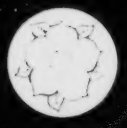

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THE ELECTRIFICATION OF THE TUMBLER RIDGE BRANCH LINE

Prepared for
Transportation Development Centre
June 1986

H. LOCKHART, A.Sc.T.
BC RAIL LTD.
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17. Abstract

BC Rail's Tumbler Ridge Branch Line was built between 1981 and 1983 to provide rail access to the North-East Coal fields in British Columbia. Because of the long grades and heavy tonnages, it was decided to electrify the branch line rather than provide complex ventilation systems in the two long tunnels. This report documents the reasons for electrification, the design, construction and commissioning of the power supply and catenary systems, the testing of the electric locomotives, the power management and the operating and maintenance costs.

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17. Résumé

Le tronçon de voie ferrée Tumbler Ridge de BC Rail a été construit entre 1981 et 1983 afin de fournir un accès ferroviaire au site minier North-East Coal en Colombie-Britannique. Vue les longues pentes et le lourd tonnage, il a été décidé d'électrifier le tronçon plutôt que d'avoir à installer des systèmes complexes de ventilation dans les deux longs tunnels. Ce rapport documente les raisons de l'électrification, l'élaboration, la construction et la mise en service des systèmes d'alimentation et de caténaires, les essais des locomotives électriques, la gestion de puissance et les coûts d'opération et d'entretien.

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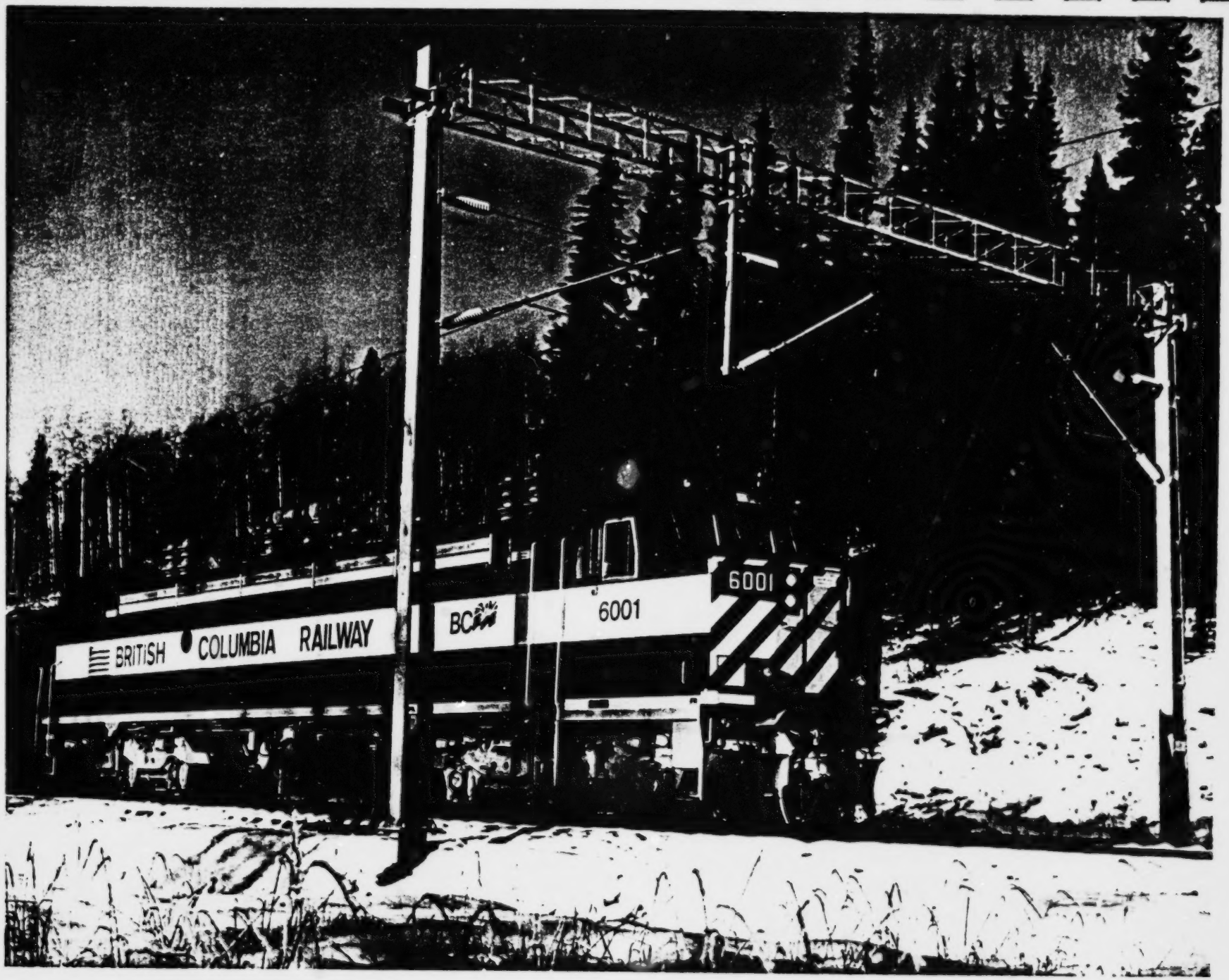
BRITISH COLUMBIA RAILWAY
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1. INTRODUCTION

During 1976, the British Columbia Railway was requested to carry out feasibility studies for rail access into the coal fields of north-eastern B.C. These coal fields held vast quantities of high-grade metallurgical coal that had a high market potential. Further feasibility studies, in 1980, concluded that a 130 km branch line could be built from Anzac on the BC Rail mainline into the coal fields for an estimated 310 million 1980 dollars.

When agreement in principle was reached for the purchase of coal by the Japanese steel industry in December of 1980, the design and construction of the Tumbler Ridge Branch Line was initiated. Using the data collected during the feasibility studies, the contracts for the first 30 km of grade were let. Construction commenced in July 1981 in the western half of the project. The eastern half began in October 1981 for the first 19 km and in June 1982 for the remaining 33 km. Grading work was completed by September 1983.

Concurrent with the grade construction was the excavation of 2 major and 2 minor tunnels. Material excavated from the Table and Wolverine tunnels was used as fill for the local railway roadbed. All tunnel work was completed by October 1983.

Prompted by the concern over ventilation in the long tunnels and with grants available from the provincial and federal governments, it was decided that the Tumbler Ridge Branch Line should be put into full electric operation. This meant that the ventilation systems, with their chimneys, ventilation fans and control gates, in the 9 and 6 km long tunnels could be dispensed with.

Design of the electrification system commenced in June 1982 and all material purchases were made by May 1983. Contracts were tendered for the installation of the substation, capacitor

station and catenary system in May 1983 and construction was primarily completed in November 1983. Coal trains powered by electric locomotives began operating on schedule in December 1983.

2. JUSTIFICATION FOR ELECTRIFIED OPERATION

In order to justify a project of this magnitude, two principal cost centres relating to conventional diesel operation were reviewed. These were the cost of purchasing diesel fuel and the cost of providing and operating a complex ventilation system in the 6 km and 9 km long tunnels. Additionally, there was funding available through the Transportation Development Centre and the Federal/Provincial Conservation and Renewable Energy programs. The economic analysis of these factors was very much site specific owing to the grades and tunnel ventilation.

There are two principal energy-related benefits derived from the use of electricity on the Tumbler Ridge Branch Line. These are: the use of less energy to move the coal from the mines to the BC Rail mainline; and the conversion to a renewable energy source from a non-renewable fossil fuel. Based on a study carried out in 1982, it was calculated that the electric locomotives of similar horsepower use 37% of the energy used by conventional diesel locomotives. The diesel locomotive consist was estimated to use 9,330 litres of high grade diesel fuel on each round trip and an electric locomotive consist would use 37.0 MW-hours of electricity. This converts to 360 gigajoules of diesel energy and 133 gigajoules of electrical energy or a ratio of 37%.

Based on the expected peak of 953 trips per annum from 1986 and energy costs in late 1982, it was expected that energy savings alone would amount to $729,000 per annum.

Other savings would be gained from reduced locomotive maintenance and elimination of the tunnel ventilation system. Partially offsetting these savings is the cost of maintenance of the substation and overhead contact system. The net savings were estimated to be in the order of $1,535,000 per annum. The actual savings are greater, as shown in the "Operating and Maintenance Costs" section of this report. Additionally there are environmental advantages because the electric locomotives are cleaner and quieter in operation and with no exhaust gases, the crews have a much safer environment when they are in the long tunnels.

3. DESIGN AND CONSTRUCTION

3.1 Description of the System

During May 1982, BC Rail began taking the necessary steps for formal ratification for this project from the provincial and federal government agencies. An immediate start was made to acquire the key components such as new locomotives, main power tranformers and the Canadian manufacturing rights for the Swedish catenary hardware.

The conceptual design analyzed a number of options from partial to fully electrified operation. The end result was that the system be fully electrified with a single 230/50 kV substation adjacent to the existing B.C. Hydro substation at Tumbler Ridge. A 2 km long 50 kV feeder from the substation would be required to transmit power to the catenary system.

The substation has two 230/50 kV single phase transformers rated at 25/33 MVA. Each transformer is large enough to supply the full demand of the system. Protective relaying for the electrified system is located in the substation. Remote control, status monitoring and telemetering of the substation,

series capacitor station, harmonic filter station and sectionalizing catenary disconnects is provided via BC Rail's micro-wave system and a micro-computer based supervisory, control and data acquisition system (SCADA) from the BC Rail head office in North Vancouver.

The catenary system is of the 'simple catenary' design. The system uses a 4/0 solid copper contact wire suspended from a 2/0 stranded messenger wire. This system is capable of maintaining contact up to 100 km/hr. A feeder line of 107 sq. mm ACSR stranded conductor on the poles parallels the contact system. The electrical return consists of 107 sq. mm ACSR stranded conductor, the continuous welded rail and the earth.

The catenary is divided into sections along its entire length. Each section, which is approximately 25 km long, can be isolated by a motor operated disconnect that is controlled via the SCADA system. This permits the load-out loops to be operational while the mainline is taken out of service.

The electric locomotives are type GF6C built by General Motors of Canada. Each locomotive has a continuously rated power of 3800 kW. This is equivalent to a maximum diesel horsepower of 6000 hp. Each traction motor is separately excited and is controlled by a wheel slip system that controls wheel creep and permits sustained adhesion levels in excess of 23% in all operating conditions with minimal sand usage.

3.2 Substation and Capacitor Station

The substation site at Km 112 was prepared by the grading contractor prior to the arrival of the substation installation contractor. The major equipment was purchased by BC Rail and supplied to the installation contractor. The major equipment was tendered and purchased by BC Rail. The Engineering Dept. determined the type and quantity of material required and

requested tenders from Materials Management. The tenders were examined for technical detail by Engineering and a recommendation made to Purchasing. On receipt of the material, it was delivered to the contractor for installation. The substation installation began May 24, 1983 and was energized on November 7, 1983.

The series capacitor was supplied on a turn-key basis and as such was supplied and installed by the same contractor. The series capacitor station was commissioned and went into service in November 1983.

All construction supervision, testing and commissioning was performed by BC Rail.

3.3 Catenary

The component parts of the catenary system were acquired by BC Rail in order to enjoy the advantages of purchasing large numbers of similar parts rather than three or four blocks of the same parts which may or may not be manufactured by the same company. Purchasing in this manner also allowed better quality control inspection during manufacture. All material was delivered to BC Rail Prince George stores to be pre-packaged on a pole specific basis. A computer program was developed by the Engineering Dept. to assist in the pre-sorting of the parts and was expanded to be used as a tool for the ongoing maintenance of the catenary system.

The construction of the catenary was split into two phases. The first phase was to install the mast foundations and erect the masts and the second phase was to erect the catenary.

One-half of the mast foundations and masts were erected by BC Rail's Maintenance of Way forces and the remaining half were erected by a local contractor. This work was primarily to drive

short piles for the foundation, weld the base plate to the pile and erect and plumb the pole. In certain instances a pre-cast concrete base or a drilled, rock anchor base was placed in the areas of the grade where the pile could not be driven to its design depth. A detailed analysis of the design of the three types of foundations is documented in Reference "3".

Once the poles were erected the catenary contractors started work to string the catenary system. The stringing operation was carried out using a pair of cable reel stands on the back of a flat deck truck and having the truck drive along the rail paying out the cables at a controlled tension. The droppers were then positioned in each span and the cantilevers adjusted for angle when the wire was at full tension. Final adjustments for stagger were then made. This work was done using basic wire stringing techniques.

The contractors erected the catenary system from Km 24 to the load-out loops by November 1983 permitting electric operation of the first coal trains in December 1983 on schedule. The section from Km 24 to the Tacheeda siding, a length of 30 km, was erected by BC Rail's own forces and equipment during April and May of 1984.

By erecting this 30 km section, BC Rail gained additional valuable experience in the construction of railroad catenary systems using modified railroad rolling stock instead of hi-rail mounted highway vehicles. Using this equipment and by having better control over labour and procedures, the cost of construction of the catenary was reduced by 35% from those bid by the contractors. The rolling stock developed is used for ongoing maintenance and new construction. See Appendix B of this report for additional information.

4. LOCOMOTIVES

Bids for the supply of the electric locomotives were solicited in 1982. General Motors of Canada was selected as the successful bidder. This was based on their locomotives having a superior sustained tractive effort and the good history of performance of General Motors electric locomotives designed in cooperation with ASEA Traction of Sweden.

The locomotives supplied to BC Rail are the GF6C model. This unit is designed to operate as a single unit or in multiple units in a consist of up to 6 locomotives. Each locomotive is supplied 50 kV AC 60 Hertz power which is transformed and rectified to 1042 Amp, 1115 V DC max current and voltage for the six E88 traction motors in each locomotive. By using thyristor control circuitry, the maximum continuous tractive effort is 400 kN at 34.5 km per hour. This tractive effort performance makes each locomotive the equivalent of a 6000 horsepower conventional diesel locomotive. Advanced radar based wheel slip detection give an extremely smooth application of power to the rail.

Each of the seven locomotives weigh 180,859 kg and is 20.980 m in length. They are painted in a distinctive colour scheme with red on the top third, white in the middle, and blue on the bottom third with a silver running gear.

The first two locomotives were delivered in late 1983. The testing of electric locomotive 6001 was commenced in November of 1983 and was completed by March 1984. Most of the tests took place on the Tumbler Ridge Branch Line between Km 81.3 and Km 84.5. This section of track has a 1.2% compensated grade with curves up to 6°. A limited number of tests were also performed on a section of track with a 1.5% grade.

The General Motors test coach ET840 was coupled to locomotive 6001 to collect the test data on its various pieces of electronic equipment. The test coach is equipped with multi channel digital and analogue recording inputs that feed signal processors and a computer. A variety of chart recorders and a printer complete the test coach's equipment.

Tests performed were primarily for adhesion at constant speeds under various track and environmental conditions. The locomotive and test car were coupled to three or four conventional diesel locomotives set to operate in their dynamic breaking mode to simulate a loaded coal train. Acceleration tests were done with one locomotive, the test coach, and a quarter-sized train of coal cars and later with four electric locomotives, the test coach, and a fully loaded coal train.

When the electric locomotives were put into service they were provided with a unique control system that controls the train at the loading silos. At other loading facilities, when the trains are turned over to the mine for loading, an operator stays in the locomotive to control the speed of the train during its 4 hour loading cycle. These trains, however, use a remote control system that allows the loading chute operator to directly control the speed of the train and the train is unmanned during its loading cycle. Other features include automatic pantograph lowering devices for the non-electrified loading silos and coal adjusting stations.

5. SYSTEM COMMISSIONING

Upon completion of the construction of each phase of the electrification system, it was commissioned. The commissioning was divided into 7 areas, these being:

1. 230/50 kV substation
2. 50 kV feeder line
3. catenary system
4. series capacitor station
5. harmonic filter station
6. supervisory control system (SCADA)
7. 50 kV//240/120 V trackside power supply

Each one of these subsystems was tested and commissioned in two stages. The first stage was to inspect the unenergized equipment for correct installation in accordance with the manufacturer's drawings and specifications. Testing at this time would ensure that the equipment would be safe and reliable when placed in service. When these tests and inspections were completed satisfactorily, the energization tests were performed.

The second stage of the commissioning was to energize each subsystem to its rated voltage and functionally test it for operation. When the energization tests were complete, the equipment was ready to be placed into service. See Appendix C for further information.

6. POWER MANAGEMENT

By December 1983, all electrification systems were substantially commissioned and placed into service such that the Tumbler Ridge Branch Line became an operating section of the railroad and at that time was renamed the Tumbler Subdivision. In order to operate in a timely manner to meet the needs of the coal mines' shipping schedules, two trains would be operating most of the time. These trains would be travelling northbound, empty from Tacheeda to Tumbler, loading at either of the two load-out loops or running southbound loaded from Tumbler to Anzac.

Each train is made up of 2 electric locomotives, 98 coal cars and a caboose. Each train, when fully laden, has a gross weight of 11,718 tonnes. Helper power is required for the southbound trains from Km 98 to Km 69 due to the grade of the track. The helper power is provided by 2 electric locomotives at the rear of the train.

The charges for electricity consumed by the electric locomotives is based on the total energy consumed and an energy demand surcharge for the greatest power drawn over short intervals of time (typically a 30 minute period). The demand charges are relatively high when compared to the total energy consumed. It is therefore in the interests of the railway's operating costs to limit the surges as much as possible.

Train performance calculator runs were made to create the theoretical train schedules that would create the optimum and worst case for cost of operation. If trains could be made to run at the optimum schedule at all times, power management would be unnecessary. However, in the real world, this is rarely the case. Schedule variations can occur due to delays at the load-out loops, incidents and maintenance on the Tumbler Subdivision and incidents and delays on the long trip between Ridley Island at Prince Rupert and the Tacheeda siding. Schedule variations can result in increased demands when two trains are pulling up grade simultaneously.

For effective power management, the dispatchers must have up to date information on energy used. This is done by the supervisory control and data acquisition (SCADA) system. The SCADA system shows the dispatcher the amount of energy being used. When a preset demand level is reached an alarm is sounded in the Train Dispatcher's office. This alarm is set such that it will sound in adequate time for the dispatcher to issue instructions to the trains so as to limit the demand levels to acceptable values.

When this critical point is close to being reached, the Dispatcher or Supervisor of Operations decides whether or not to adjust the train schedule based on the excess demand charges for the month and the cost of train delays, crew cost and revenue. The Dispatcher has direct radio contact with all trains at all times and can give instructions to any train to turn on the power limit switches in the locomotives to reduce the power to an acceptable level.

Power demands are recorded on strip charts for analysis. These charts may be compared to the Power Bureau and Train Dispatching records when train performance and schedules require modification for the most cost effective use of the electric power. For further details see Appendix D.

7. OPERATING AND MAINTENANCE COSTS

The supplementary report "Operation and Maintenance Summary - Tumbler Subdivision" compares the cost of operating and maintaining the Tumbler Subdivision both electrically and conventionally. Table 1 gives the net annual savings for various tonnages of coal to be hauled based on construction costs and operating data collected in 1984 and 1985. Appendix A contains the financial summary showing that the rate of return on the additional capital required to convert to electric operation is 20.25% without government funding and 62.95% with government funding. See Appendix E for further information.

	8.5 Million Tonnes per Year (953 trips per year)		13.5 Million Tonnes per Year (1,514 trips per year)		17.0 Million Tonnes per Year (1,906 trips per year)	
	Electric	Diesel	Electric	Diesel	Electric	Diesel
Capital Cost						
Locomotives (1)	18,366	17,000	26,160	25,500	26,160	25,500
Power supply & catenary (2)	31,420	-	31,420	-	31,420	-
Tunnel ventilation (2)	-	21,700	-	21,700	-	21,700
	49,786	38,700	57,580	47,200	57,580	47,200
Maintenance Cost						
Locomotives	622	1,181	888	1,872	888	2,362
Power supply & catenary	345	-	345	-	345	-
Tunnel ventilation	-	230	-	230	-	230
	967	1,411	1,233	2,102	1,233	2,592
Operating Cost						
Energy	1,407	4,596	1,818	7,302	2,105	9,193
Total Maintenance & Operating	2,374	6,007	3,051	9,404	3,338	11,785
Net annual savings	3,633		6,353		8,447	

Table 1 - Summary of Cost Difference Between Electric and Diesel Operation for 1986 and On (x $1,000)

(1) The cost of locomotives is the 1983 purchase cost. All other costs are in 1985 dollars.

(2) Includes interest during construction.

8. CONCLUSIONS AND RECOMMENDATIONS

The electrification of the Tumbler Ridge Branch line is an excellent opportunity to show the advantages of a 50 kV electrified railroad system where heavy tonnages, steep grades, long tunnels and an adverse environment are encountered.

The 50 kV system requires fewer connections to the high-voltage power grid than the lower voltage systems used in Eastern Canada, the United States and Europe. With the high population densities of these areas which have closely spaced power grids, it is easier to install many more substations at more frequent intervals to feed a lower voltage catenary system.

These low-voltage systems are not suitable for use in the sparsely populated regions of Canada because the main transmission lines are far apart and a lengthy feeder transmission line system would have to be built to service the necessary substations.

The 50 kV system that is used on the Tumbler Ridge Branch Line requires 25 to 50% of the number of substations needed for a lower voltage catenary. This voltage system has only been used twice before in the world. These are for the 126 km Black Mesa to Lake Powell coal hauling railroad in Arizona and the 860 km Sishen to Saldanha Bay railroad in South Africa.

There is potential to use this same system wherever there is heavy tonnage, long grades and/or high speeds affecting train operation.

A 50 kV system could be used on the other railroads crossing the Rocky Mountains in Western Canada and in the Toronto to Montreal core in Eastern Canada.

The information gained from this project is being made available to other Canadian railroads through the Railway Advisory Committee of the Railway Association of Canada. This Association meets regularly to discuss current technological advances in railroad technology. Information is also available through the Transportation Development Centre which is a part of the Ministry of Transportation of the Federal Government.

Through the BC Rail Corporate Information Service, the construction of the Tumbler Ridge Branch Line is documented on various slides, movies and technical papers and reports.

The construction of this electrification system has led to a number of observations that should be considered on any of the future electrification projects. These would include, but not be limited to, pre-training, organizing and control of the individual parts, and scheduling of catenary work around other grade work.

A comprehensive pre-training course would aid the workmen in becoming familiar with the multitude of parts, the most efficient sequence of assembling the parts into the catenary system and the safety precautions to be observed during construction.

It is necessary to have good control over the many parts required to assemble the catenary as lost or missing parts can lead to construction delays. For this purpose a computerized parts program has been developed. This program can quickly generate a list of parts to build or repair individual pole or section of poles and it lists out pertinent data to aid the maintainers in their routine inspection.

Scheduling of the work, when other activities are being performed, is important to avoid conflicts between track or ballasting crews and line stringing crews due to the continuity required in each operation.

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APPENDIX A

Financial Summary

BRITISH COLUMBIA RAILWAY COMPANY
TUMBLER RIDGE BRANCH LINE ELECTRIFICATION

8.5 MILLION TONNES

	ELECTRIC	DIESEL	SAVINGS (COSTS)
CAPITAL COST			
LOCOMOTIVES	18,366,000	17,000,000	(1,366,000)
POWER SUPPLY & CATENARY (5)	31,420,000		(31,420,000)
TUNNEL VENTILATION (5)		21,700,000	21,700,000
	49,786,000	38,700,000	(11,086,000)
LESS: FUNDING	(9,563,000)		9,563,000
	40,223,000	38,700,000	(1,523,000)
1984 (5.3 mill tonnes - 588 trips)			
FUEL (1)	3,242,000	2,730,000	(512,000)
MAINTENANCE			
LOCOMOTIVES (3)	1,050,000	700,000	(350,000)
POWER SUPPLY & CATENARY (4)	495,000		(495,000)
TUNNEL VENTILATION (4)		220,000	220,000
	4,787,000	3,650,000	(1,137,000)
1985 (7.6 mill tonnes - 851 trips)			
FUEL (2)	3,768,000	4,100,000	332,000
MAINTENANCE			
LOCOMOTIVES (3)	986,000	1,050,000	64,000
POWER SUPPLY & CATENARY	515,000		(515,000)
TUNNEL VENTILATION		230,000	230,000
	5,269,000	5,380,000	111,000
1986 & ON			
FUEL	1,407,000	4,596,000	3,189,000
MAINTENANCE			
LOCOMOTIVES	622,000	1,181,000	559,000
POWER SUPPLY & CATENARY	345,000		(345,000)
TUNNEL VENTILATION		230,000	230,000
	2,374,000	6,007,000	3,633,000

(1) 1984 FUEL COSTS:
ELECTRIC: actual fuel cost 1984 $ of $3,242,000
DIESEL: prorata based on # of trips-1984 $

(2) 1985 FUEL COSTS:
ELECTRIC: actual fuel cost 1985 $ of $3,768,000
DIESEL: prorata based on # of trips-1985 $

(3) 1984 & 1985 LOCOMOTIVE MAINTENANCE:
ELECTRIC: 1985 costs for electric's plus maintenance on the proportionate number of trips with diesel locomotives ('84 costs in 1984 $)
DIESEL : 1985 costs based on the actual number of diesel trips ('84 costs in 1984 $)

(4) 1984 costs in 1984 $

(5) includes interest during construction

Treasury, 21-Mar-86

BRITISH COLUMBIA RAILWAY COMPANY

TUMBLER RIDGE BRANCH LINE ELECTRIFICATION
WITHOUT FUNDING

Annual cost/savings (in constant dollars)
in the 20 year period 1984 - 2003

YEAR	ADDITIONAL CAPITAL COST	FUEL	LOCOMOTIVE MAINTENANCE	VENTILATION MAINTENANCE	CATENARY MAINTENANCE	TOTAL
1983	(11,086,000)					(11,086,000)
1984		(512,000)	(350,000)	220,000	(495,000)	(1,137,000)
1985		332,000	64,000	230,000	(515,000)	111,000
1986		3,189,000	559,000	230,000	(345,000)	3,633,000
1987		3,189,000	559,000	230,000	(345,000)	3,633,000
1988		3,189,000	559,000	230,000	(345,000)	3,633,000
1989		3,189,000	559,000	230,000	(345,000)	3,633,000
1990		3,189,000	559,000	230,000	(345,000)	3,633,000
1991		3,189,000	559,000	230,000	(345,000)	3,633,000
1992		3,189,000	559,000	230,000	(345,000)	3,633,000
1993		3,189,000	559,000	230,000	(345,000)	3,633,000
1994		3,189,000	559,000	230,000	(345,000)	3,633,000
1995		3,189,000	559,000	230,000	(345,000)	3,633,000
1996		3,189,000	559,000	230,000	(345,000)	3,633,000
1997		3,189,000	559,000	230,000	(345,000)	3,633,000
1998		3,189,000	559,000	230,000	(345,000)	3,633,000
1999		3,189,000	559,000	230,000	(345,000)	3,633,000
2000		3,189,000	559,000	230,000	(345,000)	3,633,000
2001		3,189,000	559,000	230,000	(345,000)	3,633,000
2002		3,189,000	559,000	230,000	(345,000)	3,633,000
2003		3,189,000	559,000	230,000	(345,000)	3,633,000
	(11,086,000)	57,222,000	9,776,000	4,590,000	(7,220,000)	53,282,000

RATE OF RETURN 20.2548%

Treasury, 21-Mar-86

BRITISH COLUMBIA RAILWAY COMPANY

TUMBLER RIDGE BRANCH LINE ELECTRIFICATION
WITH FUNDING

Annual cost/savings (in constant dollars)
in the 20 year period 1984 - 2003

YEAR	ADDITIONAL CAPITAL COST	FUEL	LOCOMOTIVE MAINTENANCE	VENTILATION MAINTENANCE	CATENARY MAINTENANCE	TOTAL
1983	(1,523,000)					(1,523,000)
1984		(512,000)	(350,000)	220,000	(495,000)	(1,137,000)
1985		332,000	64,000	230,000	(515,000)	111,000
1986		3,189,000	559,000	230,000	(345,000)	3,633,000
1987		3,189,000	559,000	230,000	(345,000)	3,633,000
1988		3,189,000	559,000	230,000	(345,000)	3,633,000
1989		3,189,000	559,000	230,000	(345,000)	3,633,000
1990		3,189,000	559,000	230,000	(345,000)	3,633,000
1991		3,189,000	559,000	230,000	(345,000)	3,633,000
1992		3,189,000	559,000	230,000	(345,000)	3,633,000
1993		3,189,000	559,000	230,000	(345,000)	3,633,000
1994		3,189,000	559,000	230,000	(345,000)	3,633,000
1995		3,189,000	559,000	230,000	(345,000)	3,633,000
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2000		3,189,000	559,000	230,000	(345,000)	3,633,000
2001		3,189,000	559,000	230,000	(345,000)	3,633,000
2002		3,189,000	559,000	230,000	(345,000)	3,633,000
2003		3,189,000	559,000	230,000	(345,000)	3,633,000
	(1,523,000)	57,222,000	9,776,000	4,590,000	(7,220,000)	62,845,000

RATE OF RETURN 62.8495%

Treasury, 21-Mar-86

APPENDIX B

The Construction of BC Rail's Tumbler Ridge Branch Line Catenary System

THE CONSTRUCTION OF BC RAIL'S TUMBLER RIDGE BRANCH LINE CATENARY SYSTEM

Prepared by: H. Lockhart A.Sc.T.

January, 1986

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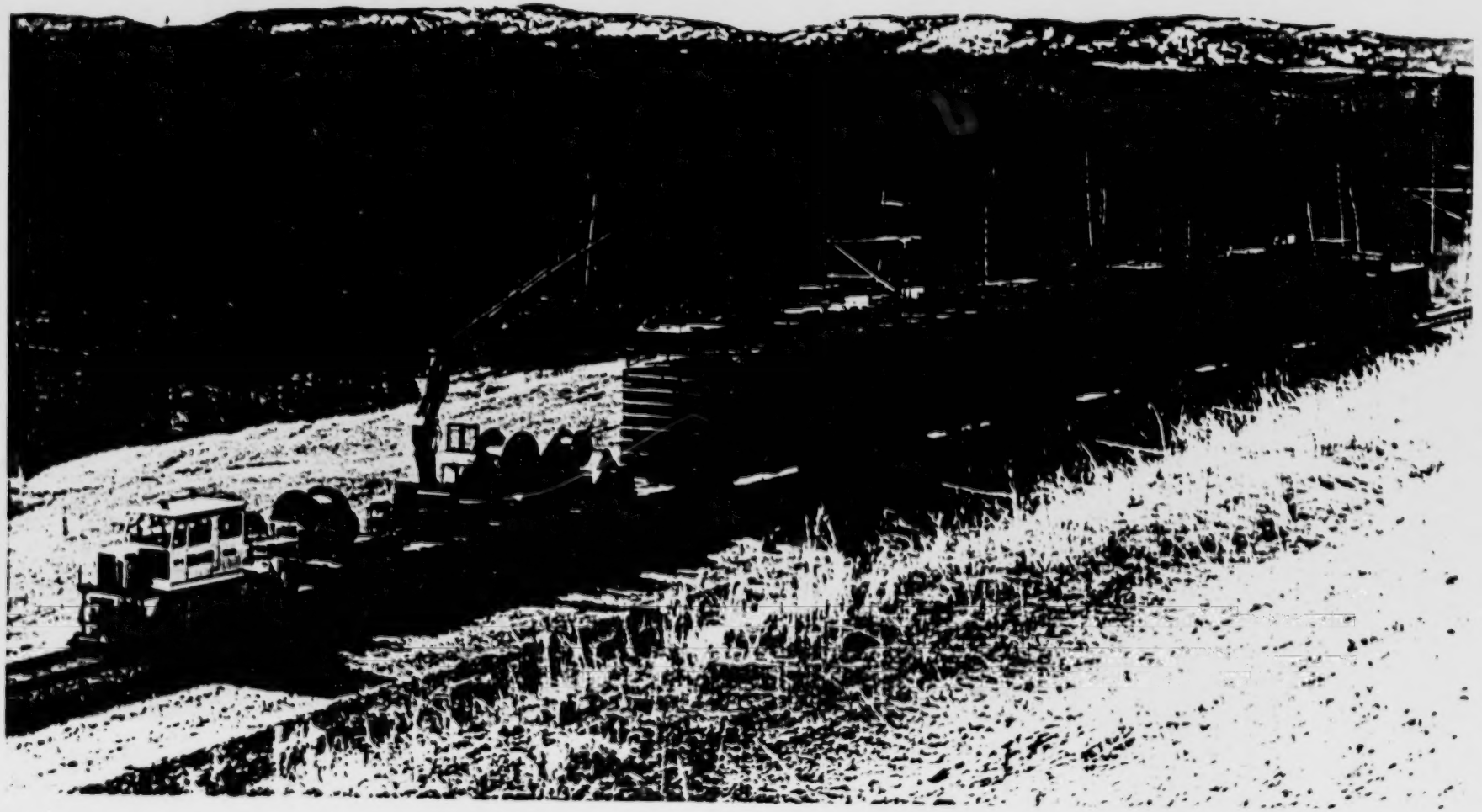


1. INTRODUCTION

1.1 Background

BC Rail first studied electrification of its rail system in some detail in 1968. At that time a study was undertaken to determine if it was economically feasible to electrify the existing railway that ran 745 km from North Vancouver to Prince George, British Columbia. At that time, it was concluded that world oil prices were such that the price of diesel fuel would need to double in order to make electrification an economic proposition.

In 1975/76, the BC Rail began design studies on rail access to the North East Coal block to transport coal to Prince Rupert, B.C. Electrification was touched on as an alternative to tunnel ventilation in the two tunnels of 9 and 6 km lengths. However, with the information available at that time, the additional rock excavation required made the project appear to not be feasible.

In 1981, electrification became an issue that was worthy of further study by the Transportation Development Centre of Transport Canada when the Railway Association of Canada publicized the use of electrification to overcome the speed limitations of diesel locomotives pulling high tonnage trains up heavy grades.

The required electrical clearances for the tunnels were then re-evaluated and the T.D.C. proposed a study to review the question of electrifying the Tumbler Ridge Branch Line.

In early April, 1982, BC Rail examined the proposal prepared by Canadian Pacific Consulting Services. By reviewing the cost of construction, the ventilation systems that would have been required in both tunnels and related operating costs, fuel cost savings, and assistance available from the Transportation Development Centre and the Federal/Provincial Conservation and Renewable Energy program, it became clear that a unique

opportunity had presented itself for BC Rail to come for the forefront in the use of 50 kV electrified railroad technology.

In June, 1982, the design of the catenary system and power supply was commenced. This was undertaken by a consortium of consultants representing Canadian Pacific Railway, Canadian National Railway, and Swedish State Railway. The catenary system is based largely on the technology developed by the Swedish State Railway on their own catenary system.

The contracts for the construction of the catenary from Km 24 to Km 129 and the two load-out loops were tendered in May, 1983. The project was ultimately awarded to three contractors with work to begin in August, 1983 and scheduled or completion by November 30, 1983. All work was performed under the supervision of BC Rail personnel. The construction was phased in such a manner that the first electric locomotives began their test program on December 1, 1983.

The section from Tacheeda to Km 24 which is 30 km in length, was built using BC Rail's own forces and equipment during April and May, 1984. The construction procedures used by Swedish State Railway to erect the catenary were followed as closely as possible. By improving on these procedures and by using BC Rail's own forces and equipment, substantial savings in construction cost were realized over those charged by the contractors the previous year.

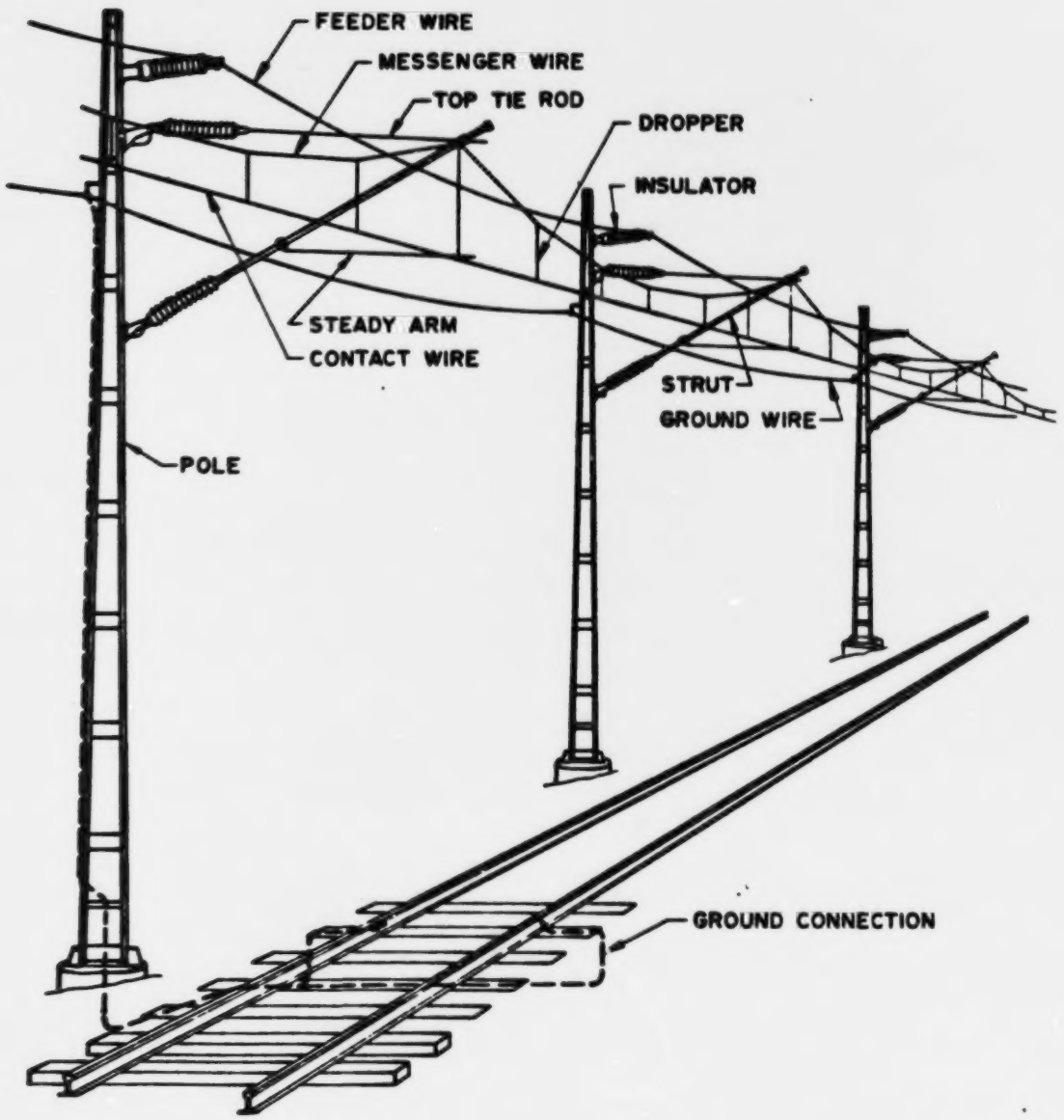
1.2 Description of the Catenary System

The catenary system runs the entire length of the Tumbler Ridge Branch Line including the load-out loops at the mine sites. The length of catenary is approximately 150 kilometers. By using a 50 kV catenary voltage, only one substation is required. The 230/50 kV substation is located at Km 112 on the branch line providing direct connection to B.C. Hydro and to allow for

expansion of the rail line eastward as more of the coal fields are developed. The substation and catenary systems were substantially built in 1983 with completion scheduled for 1984.

The Overhead Contact System (O.C.S.), see Figure 1, is of the simple catenary type using a solid copper contact wire and a stranded copper messenger wire. The catenary is supported by tubular cantilevered frames on manufactured steel masts. The masts have a maximum spacing of 70 meters on tangent track and are closer on the curves. This construction is considered to be suitable for speeds up to 100 km/hr. An aluminum (ACSR) feeder wire mounted on the catenary poles is paralleled with the contact system. The ground return circuit consists of the ground itself, the rails and an ACSR ground return conductor installed on the outside of the catenary poles.

The Overhead Contact System is divided into sections over its entire length with remote/local controlled disconnects. This enables sections of the electrified system to be disconnected for maintenance work and still allow other sections, for example the load-out loops, to be operational. The disconnects are remotely controlled from the Power Bureau located in the BC Rail head office in North Vancouver.



CATENARY SYSTEM

Figure 1

2. ERECTION OF MASTS

The system construction was implemented in two phases; the first being to install the masts and foundations, and the second to install the catenary on the previously erected masts. The supervision of the installation of the masts and foundations and construction of the catenary was performed by BC Rail Engineering personnel.

2.1 Mast Foundations

The masts and mast foundation material was procured by BC Rail prior to the award of contracts for mast erection. This was split into three sections; with BC Rail's own forces doing the work up to Km 39 and between Km 60 and Km 70, a contractor already on site doing the work from Km 39 to Km 54, and another contractor installing the masts and foundations from Km 77 to Km 129 and in the two load-out loops.

The foundations were of three types; a majority being steel H-pile and the rest either precast concrete pedestal or a set of four drilled rock anchors with a short H-pile section with a base plate to which the mast is bolted. The report "Electrification Pole Foundation Test Program" (TP 5830 E), analyzes the design and use of these three foundation types.

Both truck mounted and rail mounted pile drivers were used and 35 to 40 piles could be driven in a 12 hour shift. The pile driver mounted on a conventional truck chassis is shown in Photo 1. This unit has rigid leads that are hydraulically controlled to position the pile for driving. The other pile driver used was a rail mounted crane with a diesel operated hammer.

In one section of softer rock, where conventional rock anchor foundations were not reliable, it was found that a set of 9 holes could be drilled in a tight pattern using a pneumatic rock drill

and the pile driven into the rock. This was shown to be cheaper than a drilled rock-anchored foundation.

The rock anchor foundations were installed when the sub-base was complete. The pneumatic drill was mounted on a flat bed trailer truck to increase its mobility along the site. See Photo 2.

After completion of pile driving, the piles were cut off at a given elevation and the pile top bevelled in preparation for welding on the mast base plate.

Concrete pedestal bases were installed using a small backhoe to excavate the hole, place the pedestal, and backfill. A "jumping-jack" tamper was used to compact the backfill around the pedestal, but by keeping the width of the excavation to a minimum to avoid disturbing the sub-base, it was difficult to get good compaction.

2.2 Mast Erection

There were four types of masts used, depending on their use and the design loads placed on them. The four types of masts were designated C10, C13, C16, and C20. The C10 being the lightest pole, to the C20 being the strongest. The C10 mast is used on tangent track with a single cantilever. This is the most commonly used. The C13 mast is used on curves and at masts with the tensioning weights suspended on them. The C16 mast is used on masts with twin cantilevers at the overlaps. The C20 masts are used to support the portal frame at the sidings.

The masts were stockpiled by type in the field and loaded onto a flatbed crane truck in the order that they would be erected in the field. The crane truck would erect the masts using web straps to avoid damaging the galvanizing. The crew would then bolt the mast to the base plate to the torque value as specified. See Photo 3.

2.3 Summary

The most expedient method of installing mast foundations proved to be the driven H-pile. This could even be used where soft rock was encountered. The only problem which required careful attention during the welding of the base plates was that the base plate had to be level as any error would have a significant effect on the relative plumbness of the mast. Where the bases were not level, shims were used between the base plate and the mast base to plumb the base. In some cases the pile twisted during driving. Where the twisting was severe, filler plates were welded between the flanges to create a box section to increase the rigidity of the pile.

This portion of the work progressed smoothly, utilizing six pieces of equipment and 12 to 15 men to do the work.

3. CONSTRUCTION OF THE CATENARY SYSTEM

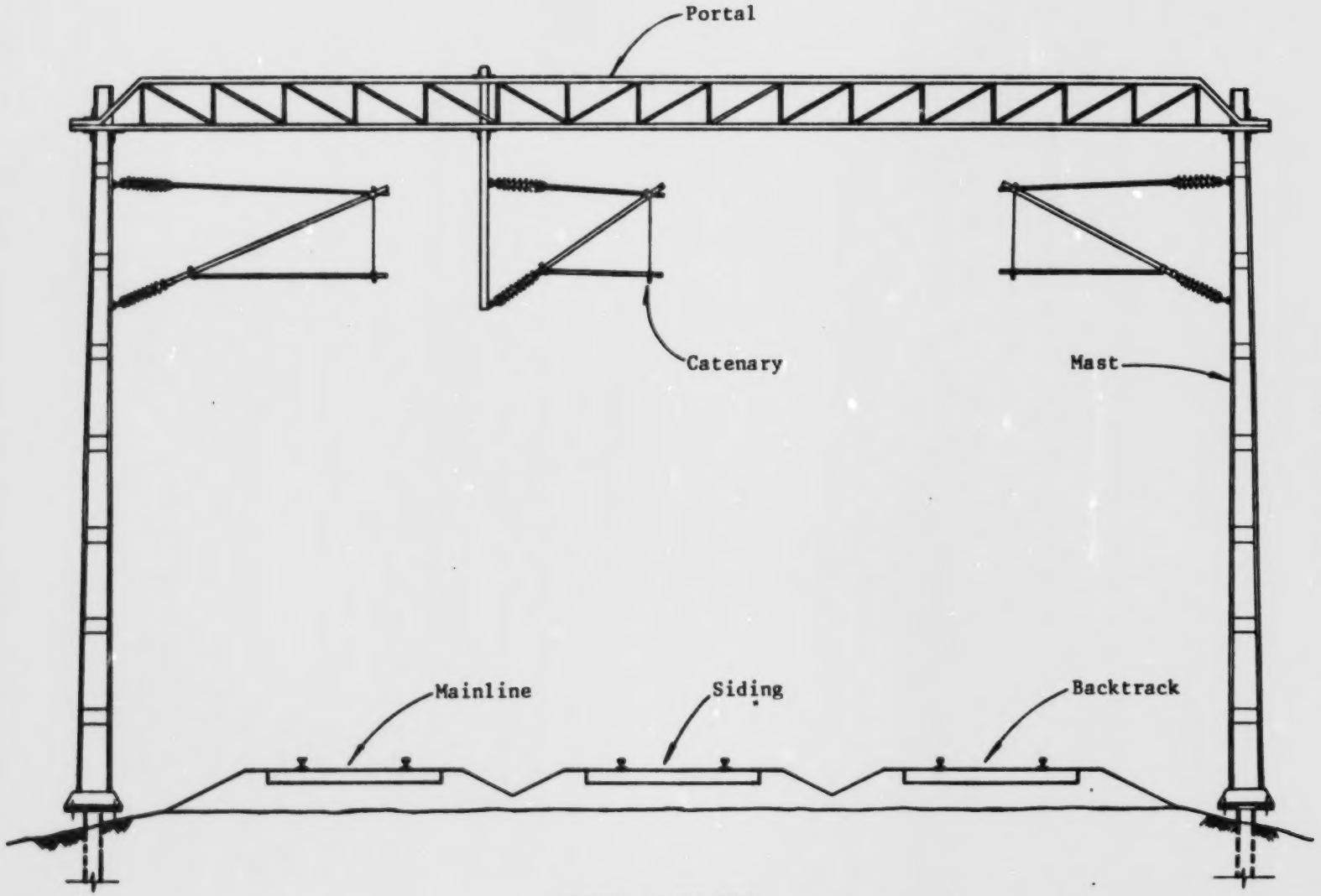
3.1 Introduction

The catenary system is comprised of a contact wire supported by droppers suspended from a messenger wire. The messenger wire and contact wires are held in place by tubular cantilever frames with ceramic insulators that are clamped to the supporting masts. (See Figure 1)

The messenger and contact wires are installed in approximately 1 km long sections with counter-weights at each end to hold a set tension in the wires.

The masts also support a feeder and ground return wire. Portals span across the sidings where there are 3 electrified tracks. (See Figure 2)

The construction of the simple catenary is primarily the assembly of the manufactured parts to create the operating system. The construction is checked using a specially built inspection vehicle. See Photo 4.



PORTAL AT SIDINGS

Figure 2

3.2 Equipment Used to Erect the Catenary

3.2.1 Tacheeda to Km 24

The construction of the catenary from Km 24 to the Tacheeda Siding on the BC Rail mainline was performed by BC Rail's own catenary forces using the equipment developed by BC Rail for long term maintenance. This specialty equipment includes the catenary maintenance cars, the inspection vehicle and the high-rail equipped bucket trucks.

The maintenance cars are a set of five modified box cars. These cars have a continuous work platform attached to the roofs. One of the cars also has a swing platform on the roof that facilitates access to the cantilevers and pole. There is also a stairway to the interior of the swing car for access to the work area. These cars are readily pulled by a shuttle wagon (Photo 5).

The inspection vehicle is a working platform built on a frame on a push car. This unit has a platform that can be extended to either side to reach the pole and an outline of a pantograph that is marked for measuring contact wire height and stagger. The inspection vehicle can be moved along the rails by a speeder or attached to a high-rail bucket truck and used in conjunction with the boom bucket.

Two of the bucket trucks used were conventional line type bucket trucks with high-rail attachments. This third bucket truck is a special truck built in Sweden that has a number of unique features.

These include:

(a) rotating rear high-rail that facilitates access to the track.

(b) vehicle control from the work platform when it is on the rail.

3.2.2 Km 24 to 129 and the Load-out Loops

The contractors elected to use conventional power line equipment with high-rail equipment added to allow running on the rail. The installation required a minimum crew of twenty workmen using a basic fleet of three bucket trucks, one platform vehicle and support vehicles.

3.3 Procedures Used to Erect the Catenary

3.3.1 Tacheeda to Km 24

BC Rail undertook the construction of the Tacheeda to Km 24 section of the catenary to gain experience and expertise for the people who would be doing the long term maintenance and future construction. All work for this section was done from the existing track. The equipment needed to move the maintenance cars was readily available from BC Rail's existing equipment and the new cars were fabricated in BC Rail's own shops using existing rolling stock as a basis. See Photo 5.

The procedure followed was primarily that which was used in the 1983 construction contracts (Appendix B). The procedure was:

1. Mark bracket locations on the poles.

2. Erect pole brackets for cantilevers, earth and feeder wires weight-tensioning.

3. String earth and feeder wires.

4. Assemble and erect the weight-tensioning and mid-point anchors.

5. Erect the cantilevers.

6. Erect the portals.

7. String the messenger and contact wires simultaneously and clip in the droppers.

8. Release counter-weights, adjust cantilevers and tighten droppers.

9. Install jumpers, grounds and erect the disconnects.

10. Cut in the section insulators and do the final adjustments.

All construction materials for this project was issued from the Prince George Stores. This material was issued in bulk with all like material in one container rather than have the material issued pole specific. Only the cantilever tube sets were pre-assembled into the various combinations of size and length but were not issued with pole numbers, only set numbers. The material was delivered to the site in rail cars that were used for storage during construction. The sets of material were made up for each pole location as the crew progressed. This method eliminated the problems of having parts missing or lost from pole specific parts bags as was used on the Km 25 to Km 130 construction program.

Marking the Poles

The inspection vehicle was used to mark the bracket locations on the poles. This operation required two people, one to mark the pole and one to operate the motor car.

Framing the Poles

Material for the day's work is prepared by the parts man the previous day ready to be loaded onto the truck in the morning. This was required only at the beginning of the work when bucket trucks are used to erect hardware.

To frame the pole with the cantilever brackets and the earth and feeder wire brackets required a crew of three and a bucket truck with a push car to carry the material. Two men were in the bucket attaching the brackets for the cantilevers, earth and feeder wire and weight-tensioning equipment, and the travellers for the earth and feeder wire stringing. The third crew man was working on the ground assembling the hardware for the next pole.

Stringing the Earth and Feeder Wires

The earth and feeder wires were run out using conventional line stringing techniques. The crew consisted of four to six people using a boom truck and two bucket trucks. Two reels were installed in reel stands on the boom trucks with the ends of the wire temporarily dead-ended to the base of a catenary pole for anchoring. The boom truck travelled down the track paying out the wire at approximately 40 kg tension.

One of the bucket trucks was close behind the boom truck hanging the wire in the travellers. At the end of the reel, the wire is tied off to the base of a pole. The two boom trucks then went along the track sagging the wire to temperature and clipping it into place in the saddle clamps on the insulators and ground wire suspension clamps. While this was being done the boom truck was getting the next reel ready and splicing onto the tied off wire to make a continuous conductor.

Erecting the Weight-Tensioning and Mid-Point Anchor Equipment

One bucket truck and a speeder with a push car were used to erect the weight-tensioning, guying and mid-point anchors. Material for the weight-tensioning equipment was loaded into the bucket truck and the guying material was carried by the speeder push car. The crew in the bucket truck erected the material related to the weight-tensioning that is suspended by the weight-tensioning pole, the top end of the guying and the mid-point anchors. The ground crew pulled the guys up to tension and made the bottom connection at the guy wire anchor.

Erecting the Cantilevers

To erect the cantilevers, the swing-stage car from the maintenance train and shuttle wagon were used. The swing-stage car's lower floor was used to store the material for the day's work and to organize the parts for each cantilever as the car moved from pole to pole. The assembly of the cantilevers was done by a crew of three from the top deck of the swing-stage car. The top deck of this car gives a large deck to work from to assemble the cantilevers. Photo 7 shows the cantilevers being fabricated inside the car and Photo 8 shows the cantilevers being erected from the platform on the same car.

While the cantilevers were being built, two bucket trucks and the boom truck with their crews were erecting the portals at the Tacheeda Siding. See Photo 6.

Stringing the Contact and Messenger Wire

Contact and messenger wire was strung using the catenary maintenance train with a flat car for the reel tensioners and a shuttle wagon to move the cars. This operation required a crew of seven plus a shuttle car operator, a pilot and two trainmen.

See Photo 9. Photo 10 shows the dynamometer being used to tension a section prior to releasing the weights.

The procedure used was the same as that used by the Swedish State Railway. A copy of this procedure is attached in Appendix B.

Adjusting Cantilevers and Installing the Droppers

Once the contact and messenger wires were clipped in place and under full tension by releasing the weight, the cantilevers were adjusted for temperature and the dropper clamps were tightened in their correct position. This work was done by a bucket truck and a crew of two.

Installing Jumpers and Equalizers

Electrical jumpers, potential equalizers, feeder jumpers and grounding was done by a crew of three using a bucket truck and a speeder. This crew followed along behind the adjustment crew.

Cleanup and Commissioning

With final cleanup and commissioning, the catenary system was completed from the two mine load-out loops to the BC Rail mainline at the Tacheeda Siding. The first electric locomotive arrived at Tacheeda on June 1, 1984.

Maintenance Inspections

Scheduled maintenance inspections are performed using a catenary maintenance car that has a pantograph used to measure stagger and a video camera to record the interaction of the pantograph and contact wire. See Photo 11.

3.3.2 Km 24 to 129 and Load-out Loops

Prior to the installation of hardware, the top of rail was marked on the masts. This mark is the bench mark that the contact wire height is set to.

Catenary work is such that a logical sequence of steps are undertaken to erect the system. The procedure is:

1. Erect pole hardware and portals.
2. Install guy anchors.
3. Erect feeder insulators and ground wire saddles.
4. String the ground and feeder wires.
5. Erect the cantilevers.
6. Assemble and erect the weight-tensioning and mid-point anchor hardware.
7. String the messenger wire and contact wire.
8. Release counter-weights and adjust cantilevers.
9. Install droppers between the messenger and contact wire.
10. Install jumpers for grounds, feeders and overlaps.
11. Install disconnects and section insulators.
12. Do final catenary adjustments.
13. Install grounds to rail.

There is sufficient versatility in this method so that when one crew is finished doing one function they can go on to another step.

The stringing of the messenger and contact wire was undertaken using two different methods, either of which proved satisfactory. The standard method used in Sweden is to string the messenger and contact wires simultaneously. The other method is to first string the messenger wire and then to string the contact wire in the next operation. Both methods were used on this project. Refer to Appendix C for the detailed procedures.

The installation of the catenary required a minimum of three high-rail trucks, one platform vehicle and 20 workmen plus support vehicles. Some catenary was installed from the sub-base prior to track laying but a majority was installed from the rail using high-rail equipment. Construction equipment varied with each contractor depending on how many crews and work locations were concurrently in operation.

3.4 Production Rates and Costs

Table 1 compares the manpower, equipment and rate of production between the work done in 1983 by the contractors and the work done by BC Rail's forces in 1984. Cost savings realized by using the catenary work train and BC Rail personnel amounted to $10,200 per kilometer. The total bid price to construct the system averaged $27,625 per kilometer. The final cost of erecting the Tacheeda to Km 24 section by BC Rail was $17,425 per kilometer.

	BC Rail		Contractors	
	Crew Size	1984 Daily Production	Crew Size	1983 Daily Production
1. Framing poles	3	35/day	4	30/day
2. String earth and feeder wire	4-6	2.0 km/day	4-5	1.5 km/day
3. Erect weight-tensioning & midpoint anchors	3	2 sects/day	4	3 sects/day
4. Erect cantilevers	4	1.8 km/day	6-7	1.7 km/day
5. String contact & messenger wire	7	2.3 km/day	5	1.2-2.3 km/day
6. Adjust cantilevers & tighten droppers	2	2.1 km/day	3	1.2-1.8 km/day
7. Install jumpers	3	35-40/day	2-3	10-20/day
8. Final adjustments	3	4.8 km/day	3	1.2-1.8 km/day
9. Net cost to erect the catenary		$17,425/km		$27,625/km

TABLE 1 - Production Rates and Crew Sizes

4. OBSERVATIONS ON CONSTRUCTING THE CATENARY

A catenary work train has been developed by BC Rail utilizing 5 boxcars with a working platform on the top, a wire stringing car, and an inspection car. This will give working access to 70 to 80 meters of the catenary at a time. This unit is proving to be very versatile as it has parts storage and working area built in to it. It has been used for construction but its primary purpose will be for long term maintenance and repairs.

There are several factors to be considered when building a catenary system. These include training, organization and control of parts inventory, and scheduling of work.

This is the first operating catenary system of this type to be built in British Columbia by local contractors. The experience gained by Vancouver linesmen on the Vancouver d.c. trolley system would have been helpful but the tradesmen employed on the Tumbler Ridge project were familiar with only simple power line construction. Consequently, a training program should be a pre-requisite for any contractor undertaking this work to ensure familiarity with the parts and procedures.

A comprehensive training course would help the workmen to become familiar with the material to be installed, the equipment to be used, the procedures used to erect the system, the reasons for doing the work in this manner, and the safety precautions to be undertaken before the work begins. A course of this nature would minimize the problems created by unorganized parts inventory and control and reduce the learning curve in becoming familiar with the multitude of parts. It would also show how everything fits together and functions, and help the workmen understand what happens when the messenger wires and contact are not installed at the proper tension. In order for the work to proceed in an orderly manner, the parts must be organized on site and in a way that the inventory can be controlled and organized for the erection crews. The individual crew should stay on one function until complete so that parts for that function do not get spread out among two or three crews. The method adopted by one contractor was to have one three-man crew to organize the parts and another crew to distribute the parts to the work site. This way the parts crew could identify the shortages prior to the field work being disrupted for lack of parts and the work proceeded smoothly.

A computerized system of parts control has been developed for the Branch Line. This system has two purposes. The first is to be able to quickly generate a list of parts required to build or repair a section of the catenary. The second purpose is to aid the maintainers by providing a bill of materials of the parts that are on each pole and a list of staggers for their routine inspections.

Training of all personnel involved in the catenary construction should be undertaken before the work begins. The people representing BC Rail participated in a two week training course that covered both theory and hands-on experience with an active catenary system that was the basis for the Tumbler Ridge Branch Line catenary. The benefit of this training was passed on to the BC Rail site inspectors in sessions prior to the start of construction. Three or four days of training sessions for the contractors would substantially reduce the learning curves for each phase of the work and thereby reduce the construction time. The contractors assumed that the catenary system was a variation of a power line construction project. However, there was difficulty in accepting the concept that the catenary is a dynamic working mechanism unlike a static power line and a higher degree of accuracy is required to build the system correctly.

Safety during the construction of the catenary, particularly during stringing of the contact and messenger wire should be stressed. When the messenger and contact wires are being strung around curves with the cantilevers on the inside of the curve, it is very easy for the cantilevers to slip and collapse causing the wires to slip towards the masts.

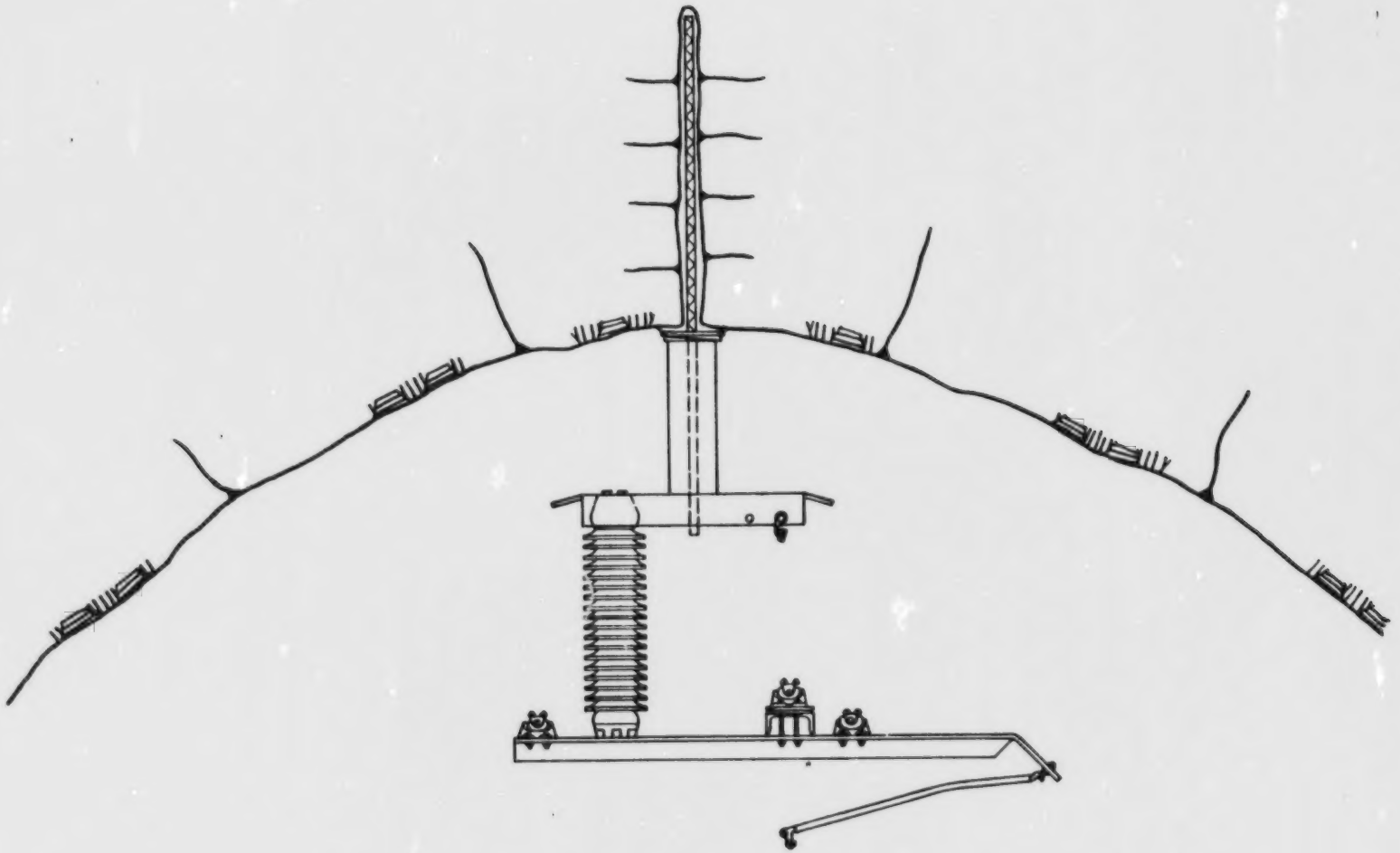
General safety must also be stressed. For example, if anyone is standing inside the wire, they will be seriously injured if the wire slips. This slippage can be prevented by temporarily guying some of the cantilevers in the curve and using the proper

stringing tension in the wire and always working on the outside of the wires.

Scheduling became very important on this project when there were many concurrent activities. These included tracklaying and ballasting. In the sections where the catenary was built before the track was in place, the catenary was set to its theoretical location, then adjusted after the track was in place. Because the catenary was generally constructed immediately after the track construction, it will need more attention than it would if it was built in an existing line. During the early years of any new grade there is always a degree of settlement and consolidation in the roadbed. Consequently, this will require continuous checking and adjustment of the catenary to maintain its correct alignment.

There were no major problems in erecting the tunnel catenary because the contractor was familiar with the system by then. The tunnels are of a fixed tension design like a power line and are simpler to construct. The cantilevers were all a similar type, suspended from rock bolts in the tunnel roof. (See Figure 3)

Turnbuckles were used in the Table Tunnel to allow for final sag adjustments to be made after difficulties were experienced in the Wolverine Tunnel. There were several small design changes during construction, but these were to be expected because of the complexity and overall size of the system. Also, it became evident as the work progressed, that a number of parts could have been standardized, thereby reducing the overall number of types of parts and making the erection simpler.



Tunnel Cantilever

Figure 3

5. SUMMARY

The construction of the catenary system was completed to a point such that by the end of November, 1983 the Tumbler Ridge Branch Line entered into its testing phase and limited electric operation. By the spring of the following year the Branch Line was in electric service from Km 24 through the Table and Wolverine tunnels and the two load-outs. It then remained a matter of completing the construction to the Tacheeda siding to make the system fully operational with electric locomotives. This was completed in April, 1984.

Foundations are to be closely watched for settlement. Small movements of the footing cause substantial movements of the contact wire and create conditions where the contact wire will not make contact with the pantograph.

During construction of the catenary a number of procedures were used to erect the cantilevers. These ranged from no prefabrication to doing as much prefabrication as possible. The preferred method is to pre-assemble as much as can be done, then to erect the sub-assemblies to theoretical settings.

Stringing of feeder and ground conductors was straightforward. Some ran out the conductors by transporting the drums and other pulled the conductors through pulleys with a rope.

Simultaneous stringing of the messenger and contact wires proved to be more difficult due to the grabbing and slipping of the disc brake on the tensioning drums. It was found that by increasing the speed of the truck, this effect was minimized. A hydraulic braking motor would also minimize this effect.

During the stringing of the messenger and contact wires on inside curves, it was often necessary to temporarily guy the cantilevers to prevent their collapse due to a brief excessive tension on the wire.

Typical line equipment was used on this construction project. Modifications were made to suit the function. A large platform was welded to the top of a high-rail equipped dump truck to provide a working deck for dropper installation and bucket trucks were equipped with various modifications for the work.

6. REFERENCES

1. Design, Construction and Performance Monitoring of Electrification Poles and Foundations on BC Rail's Tumbler Ridge Branch Line. TDC Report No. TP5830E by J.C. Leighton, P.Eng., BC Rail. November, 1984.

APPENDIX A

PHOTOGRAPHS

Photo 1 - Truck Mounted Pile Driver

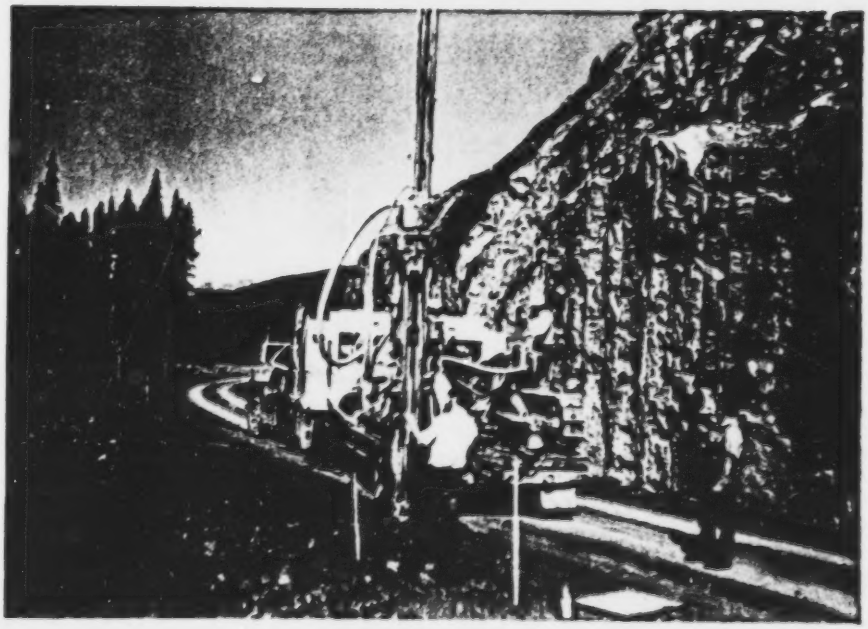


Photo 2 - Trailer Mounted Pneumatic Drill

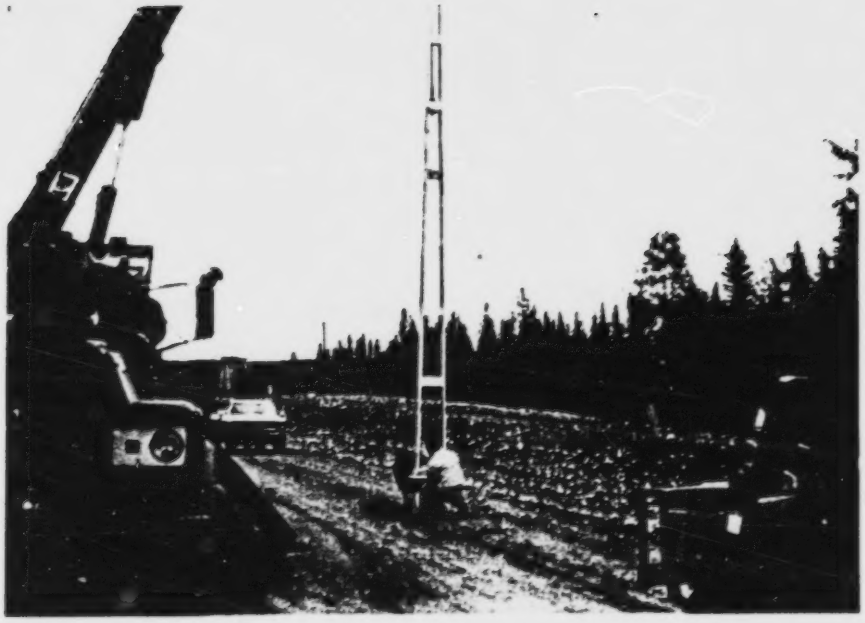


Photo 3 - Erecting a Mast

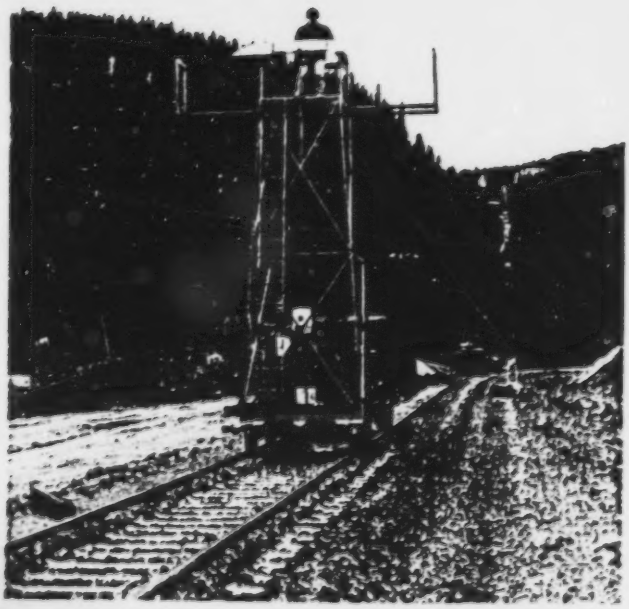


Photo 4

Construction Inspection Car

Photo 5 - Catenary Repair Unit

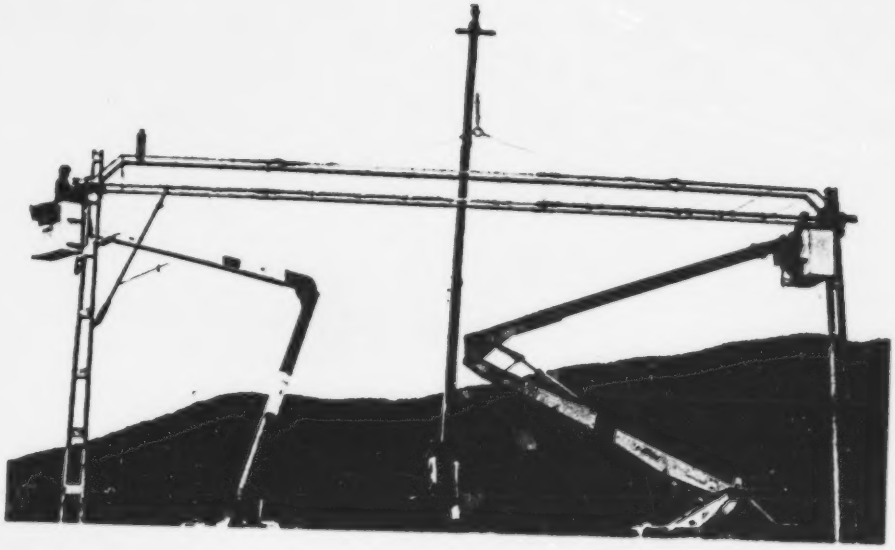


Photo 6 - Erecting a Portal

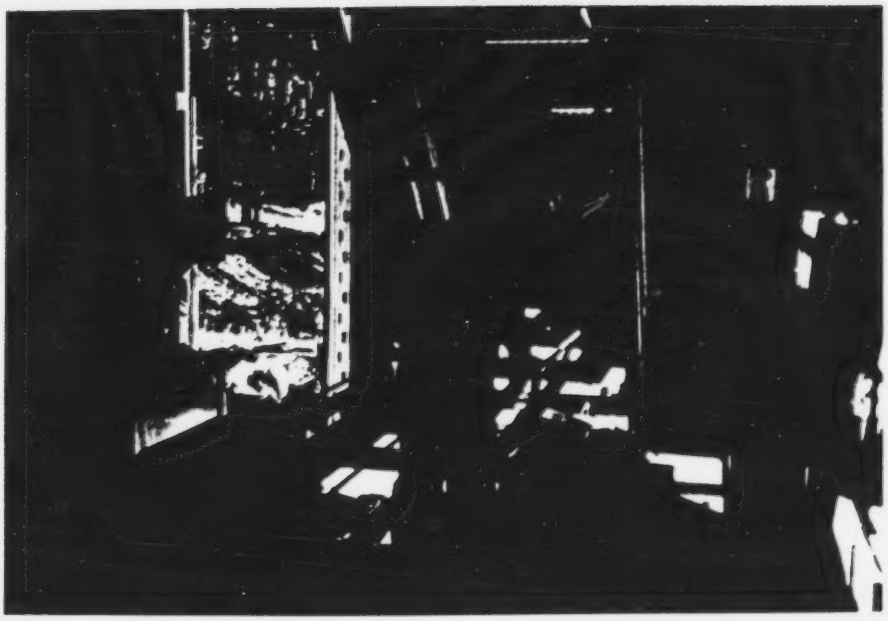


Photo 7 - Fabricating a Cantilever

Photo 8 - Erecting a Cantilever

Photo 9 - Stringing Messenger and Contact Wires

Photo 10 - Tensioning a Section

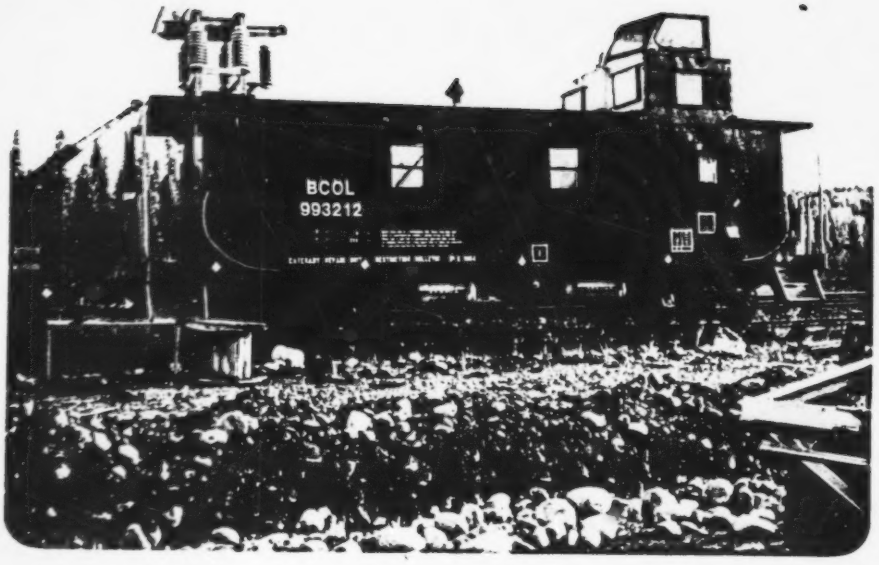


Photo 11 - Catenary Inspection Vehicle

APPENDIX B

EXCERPT FROM THE
"OVERHEAD CONTACT SYSTEM INSTALLATION"
"TUMBLER RIDGE BRANCH LINE"
CONTRACT NO. 1163-76-76

2.22 Wire Erection Techniques

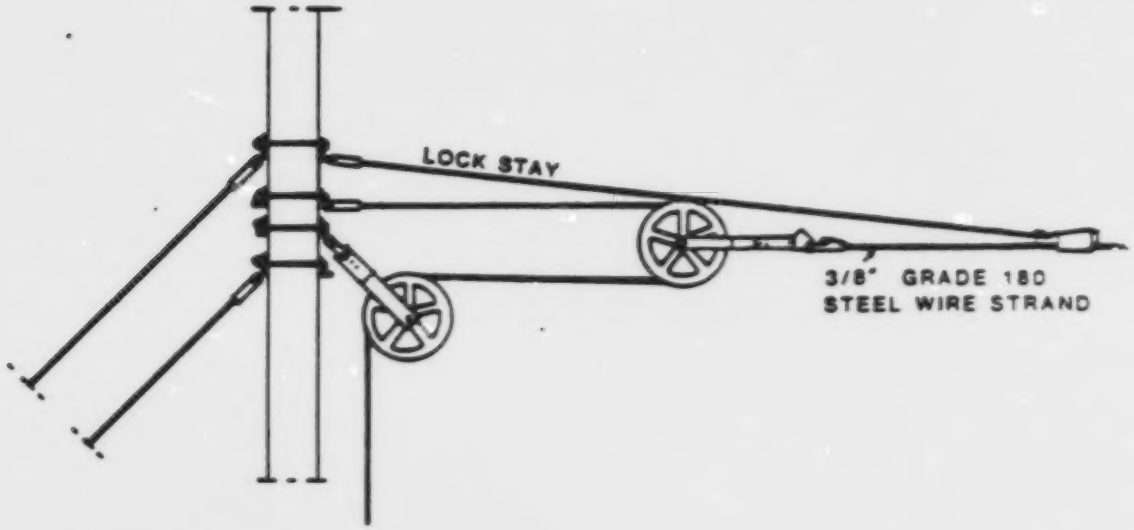
Two basic procedures have been used elsewhere for installing messenger and contact wires. The method used by Swedish State Railways, where the design of this overhead contact system was developed, involves stringing messenger and contact wires together, under controlled tension. For ease of installation, this method requires wire stringing to start at the crossed end of an overlap to avoid the inconvenience of threading the tensioned wires down the full length of the overlap at commencement.

An alternative procedure for installing catenary, stringing the two wires separately, requires a knowledge of the no-load or unloaded tension in the messenger, that is the required tension before the weight of the droppers and contact wire is applied.

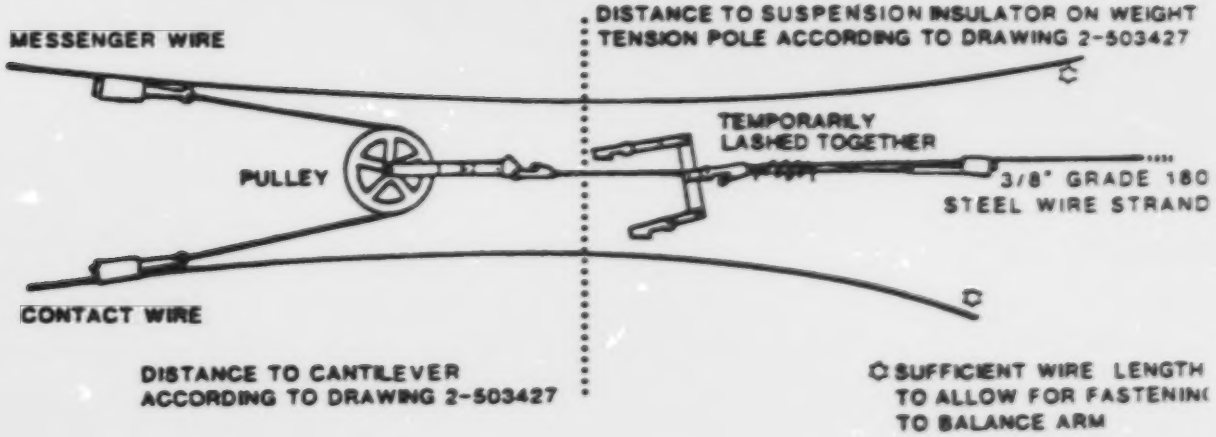
It is assumed that all cantilevers, weight-tensioning equipment and guys are installed according to the applicable Assembly and Layout Drawings for the line section in question prior to the messenger and contact wire stringing operation. Step-by-step descriptions of the two methods are now given.

2.22.1 Swedish State Railways Procedure

1. Secure the weights at the starting point in the approximately correct position (according to Drawing 2-503285) by means, for example, of a block and tackle from the top of the pole to the weights and of a temporary "lock stay" as per drawing below:



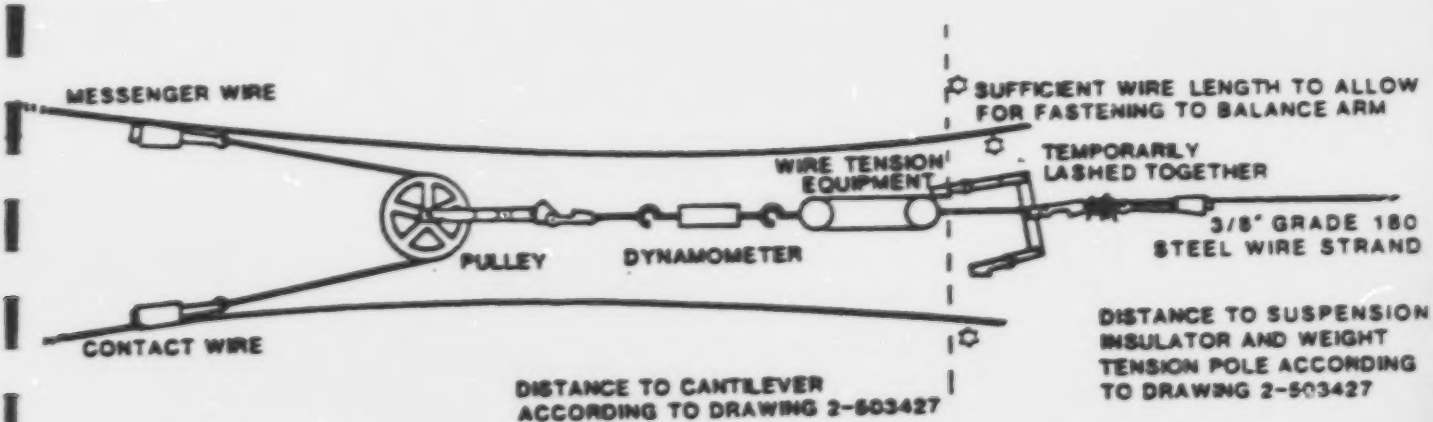
2. Secure the messenger and contact wires to the steel wire temporarily and leave the balance arm unconnected as per drawing below:


MESSENGER WIRE
DISTANCE TO SUSPENSION INSULATOR ON WEIGHT TENSION POLE ACCORDING TO DRAWING 2-503427
TEMPORARILY LASHED TOGETHER
PULLEY
3/8" GRADE 180
STEEL WIRE STRAND
CONTACT WIRE
DISTANCE TO CANTILEVER ACCORDING TO DRAWING 2-503427
SUFFICIENT WIRE LENGTH TO ALLOW FOR FASTENIN(TO BALANCE ARM

3. The messenger and contact wire drums are both positioned in trestles with brakes on a flat car, high rail vehicle or equivalent and moved along the line section. The wires are paid out through a boom with two pulleys at approximately the same height as the installation height of the two wires. The messenger and contact wires are positioned in their clamps at the cantilevers as these are encountered. The bolts in the clamps are not tightened with the final torque, but only enough to secure the cantilevers to the wires. In each span, two or three temporary droppers lash the contact wire to the messenger.

   The first cantilever after the weight tension is off-set towards the weight tension by approximately 50 mm, and at the subsequent cantilevers the off-set is increased to a final off-set at the last cantilever of approximately 500 mm.

   The messenger and contact wires are both paid out with a brake force amounting to approximately 70% of the final tensioning force. At the last span, before the weight tension pole at the end of the line section, full brake force is applied on both drums. After having passed the last pole before the weight tension pole, the messenger and contact wires are terminated to a pulley, a dynamometer, wire tensioning equipment and the balance arm according to the following drawing:


MESSENGER WIRE
SUFFICIENT WIRE LENGTH TO ALLOW FOR FASTENING TO BALANCE ARM
TEMPORARILY LASHED TOGETHER
WIRE TENSION EQUIPMENT
3/8" GRADE 180 STEEL WIRE STRAND
PULLEY
DYNAMOMETER
CONTACT WIRE
DISTANCE TO SUSPENSION INSULATOR AND WEIGHT TENSION POLE ACCORDING TO DRAWING 2-503427
DISTANCE TO CANTILEVER ACCORDING TO DRAWING 2-503427

4. Full tension is now applied to both wires and the balance arm is installed and adjusted according to Drawing 3-503286. Prior to this operation, the weights will have to be secured into the approximately correct position as per Drawing 2-503285; for example, by means of a block and tackle from the top of the weight tension pole to the weights. The weights are released immediately prior to the installation of the balance arm, and the final adjustment is done with wire tensioning equipment.

5. The cantilevers will now be in the approximately correct position due to the off-set during the wire stringing operation; and the final adjustment of the cantilevers position is done according to Drawing 3-503430 and 3-503431 (including final tightening of the bolts in the clamp).

6. Referring to the numbers on the sketch at the end of Section 2.22.1 entitled "Sequence of final adjustment of Cantilevers", the sequence and methodology of adjustment of cantilevers is as follows:

   (a) Installation of the midpoint anchor (1) and adjustment of the midpoint anchor cantilever perpendicular to the track according to Drawing No. 2-503411.

   (b) Insert wire tensioning equipment between the pulley and the steel wire strand, and adjust the weights into their correct position. Install the balance arm and adjust per Drawing 2-503286. Remove the lock stay and release the weight (2).

   (c) Adjustment according to Drawing 3-503430 of all cantilevers in between the midpoint anchor and the overlap starting from the midpoint anchor going backwards (3).

   (d) Adjustment according to Drawing 2-503431 of the twin arm cantilever in the overlap where the wire stringing started (assuming that the previous line section has been installed).

   At insulated overlap spans, the twin cantilevers shall be adjusted per Drawing 3-504158 (4).

   (e) Adjustment according to Drawing 3-503430 of all cantilevers in between the midpoint anchor and the other overlap starting from the midpoint anchor moving forward (5).

   (f) The sequence repeats from (1) to (5), identified as (6) to (9) on sketch, after the stringing of the next tension length (section).

7. The number of droppers and their lengths for different spans are given in the tables for droppers, Drawing 2-503778. Bundles of droppers will be prepared and identified for each span. The droppers are installed in the same sequence as the final adjustment of the cantilevers. Following the adjustment of the cantilever for each span, the droppers are installed before moving on to the next cantilever.

Sequence of final adjustment of cantilevers

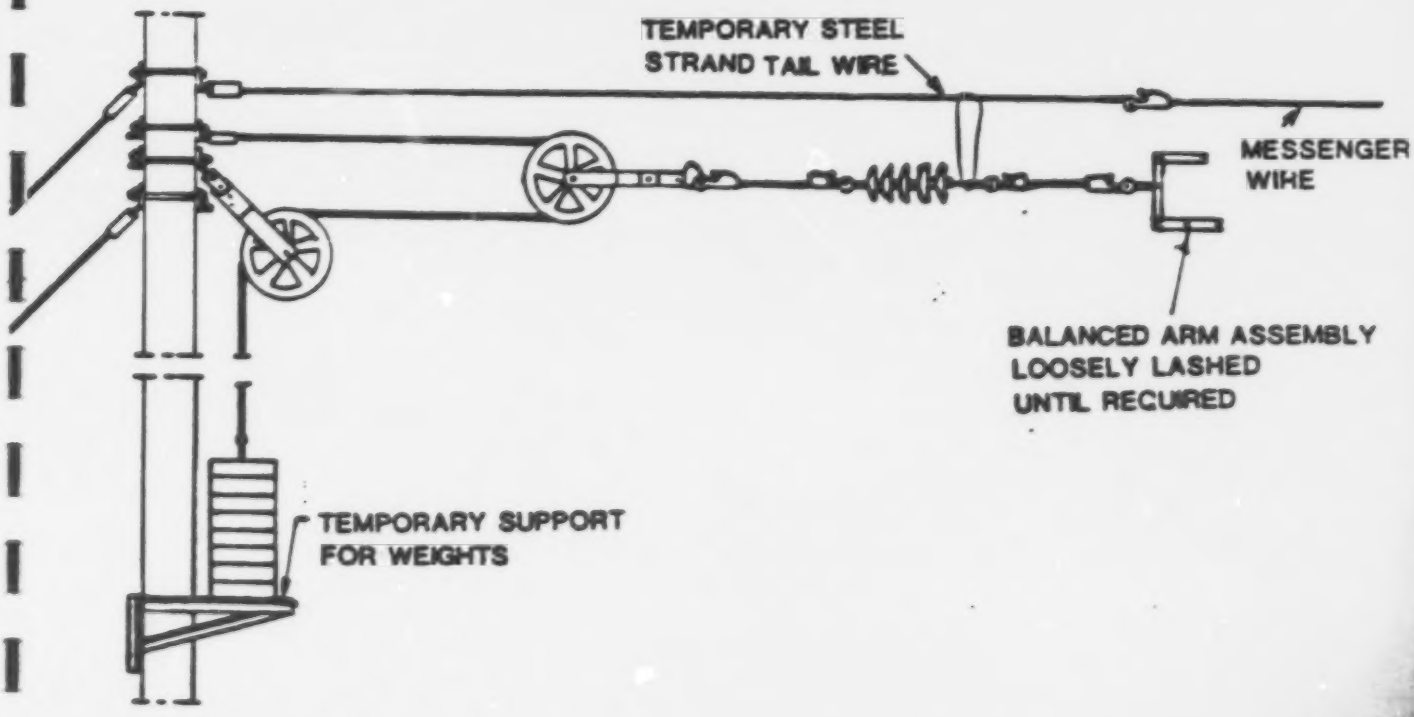
Initialled by: _____ Contractor _____ Company

2.22.2 Alternate Procedure

1. Secure the weights at each end of the section at the approximately correct position (according to Drawing 2-503285) by means of a support bracket or other suitable means.

2. The wire drums are assumed to be mounted on trestles, with brakes, on a flat car, high rail vehicle or equivalent, coupled to or working in conjunction with a high-level mobile work platform having an effective length equal to something greater than one span.

3. Secure the messenger wire temporarily to a steel wire strand behind the balance arm using a long tail wire shown in the sketch and move reel toward distant anchor lifting the wire into running sheaves attached to the nose of each cantilever. Cantilevers should be off-set to the track roughly in accordance with Drawing 2-503430. Cantilevers, especially cantilevers on the inside of curves, may require tieing back to resist along-track drag. The tension in the messenger is arbitrary, but should be enough to provide approximately the required sag but continue to make the wire handleable.



4. At the distant anchor pole stop paying out messenger wire and tension the messenger in line with the anchor pole to the required no-load tension. Secure the tensioning messenger to a steel strand behind the balance arm, again using a long tail wire to the anchor pole.

5. Droppers may now be attached throughout the section.

6. Contact wire is similarly attached to the temporary steel wire strand and run out under relatively high tension. At each dropper and cantilever registration tube the contact wire is suspended in a temporary wire hook. At the last pole, the contact wire is tensioned to normal tension and both messenger and contact wire can be attached to the balance arm and the balance weights released.

7. The messenger and contact wire may now be attached to the balance arm at the starting end of the section and the balance weights released, making sure that tension is evenly distributed throughout the section, by inspection.

8. Hangers may now be secured in position, cantilevers set correctly, the messenger clamped in place and registration arms secured to the contact wire.

9. Balance arms should be checked and adjusted, and balance weights checked for freedom of movement.

APPENDIX C

Tumbler Ridge Branch Line Electrification
Interim Commissioning Report

TUMBLER RIDGE BRANCH LINE ELECTRIFICATION

INTERIM COMMISSIONING REPORT

BY

JOHN POPOFF, P. ENG.
ELECTRICAL ENGINEER
BRITISH COLUMBIA RAILWAY
NORTH VANCOUVER, B. C.

APRIL, 1984

PROJECT TEAM

THE PROJECT TEAM FOR B. C. RAIL WAS COMPOSED OF:

P. H. BRIDGE

J. POPOFF

ACKNOWLEDGEMENTS:

The authors gratefully acknowledge the advice and assistance provided by the personnel of Canadian Pacific Consulting Services Ltd., United Power Ltd., Chippendale Electrical Services Ltd., Omega Technical Services Ltd., Houle Electric Ltd., Nokia Engineering, ASEA, and Canadian General Electrical Company Ltd.

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APPENDIX A	ELECTRIFICATION - ONE LINE DIAGRAMS
APPENDIX B	230/50 KV SUBSTATION TEST RESULTS
APPENDIX C	230/50 KV SUBSTATION - PROTECTION AND CONTROL
APPENDIX D	SERIES CAPACITOR STATION TEST RESULTS
APPENDIX E	HARMONIC FILTER STATION TEST RESULTS

1. SUMMARY

1.1 Background

In 1968, the British Columbia Railway first studied electrification of its rail system to determine if it was economically feasible to electrify the existing railway from North Vancouver to Prince George (a distance of 745 km). It was concluded that the world price of diesel fuel would need to double in order to make electrification economically viable.

In 1975/76, British Columbia Railway began studies on rail access to the proposed North East Coal Development for the purpose of transporting coal to Prince Rupert, B.C. Electrification was considered as an alternate to forced ventilation of a 6 km and a 9 km tunnel. The additional rock excavation required made electrification appear to be economically unfeasible.

In 1981, electrification became worthy of further consideration when the Railway Association of Canada publicized electrification as a means of overcoming the speed limitations of diesel locomotives powering high tonnage trains on heavy grades. The Transportation Development Centre of Transport Canada proposed a study to review electrification of the Tumbler Ridge Branch Line.

In April, 1982, B.C. Rail examined a proposal prepared by Canadian Pacific Consulting Services Ltd. Upon reviewing the anticipated operating costs, capital savings; and incorporating the assistance available from the Transportation Development Centre and the Federal/Provincial Conservation and Renwable Energy Program, it became clear that B.C. Railway was in a position to move to the forefront in 50 kV electrified railroad technology.

In June, 1982, a consortium of consultants representing Canadian Pacific Railway, Canadian National Railway, and Swedish State Railway, began detailed design of the catenary system and the power supply. Approval to proceed with electrification was granted in July, 1982.

Electrification construction began in May, 1983, with completion such that limited electrical operation was possible in December, 1983.

1.2 Purpose

This report is intended to document the testing and commissioning procedures incorporated in bringing the high voltage fixed plant facilities associated with 50 kV electrification of the Tumbler Ridge Branch line into regular commercial service.

2. INTRODUCTION

2.1 Electrification System Summary

A single source 50 kV, 60 Hz catenary system was selected for the Tumbler Ridge Branch Line electrification. The catenary system feed is connected at Km 112. A 2 km wood pole 50 kV feeder line connects the catenary with B.C. Rail's 230/50 kV substation (see Appendix A).

A single 230 kV, three phase, 60 Hz circuit feeds B.C. Railway's substation. Two 25/33 MVA ONAN/ONAF single phase power transformers (T1 and T2) are connected between phases A and B. T1 and T2 secondary windings are connected 50 kV phase to ground.

Both transformers feed a 50 kV single phase normally closed split bus with three feeder breakers. Two of these breakers (5CB-L1, 5CB-L2) are dedicated to the catenary supply. Both circuits are paralleled and only one breaker is intended to be in service at one time. Both catenary feeder circuits are equipped with single shot automatic reclosing to clear transient faults. The third breaker (5CB-C1) connects a 7MVAR shunt capacitor/3rd harmonic filter combination.

Catenary line voltage regulation is provided at Km 67 by means of a -j 15 ohm, 800 A series capacitor station. Approximately 28% compensation is provided.

Harmonic overvoltage protection is provided by means of a 5th harmonic LC filter and a high pass RC filter (7th harmonic and above) located at Km 67.

Catenary sectionalizing and siding switching is realized via motor operated disconnect switches. These switches are serviced by 50 kV//240/120 V, 75 kVA single phase trackside power supplies fed from the catenary.

The substation, series capacitor, harmonic filter station, and catenary disconnects are remotely supervised and operated from B.C. Railway's North Vancouver dispatch centre via microwave communications. Supervision and control is effected by a CRT and keyboard accessed microprocessor based SCADA system.

2.2 Testing Overview

For the purposes of construction and commissioning, the electrification was subdivided into the following discreet subsystems:

1. 230/50 kV substation.
2. 50 kV feeder line.
3. catenary system.
4. series capacitor station.
5. harmonic filter station.

6. supervisory control system (SCADA).

7. 50 kV//240/120 V trackside power supply.

In general, each subsystem testing and commissioning was performed in two stages:

(a) Pre-commissioning and commissioning tests

These tests were performed to ensure that all equipment was delivered and installed in accordance with the specifications and design drawings. Tests and inspections were conducted to ensure that the equipment, as supplied and installed, would provide reliable and safe service. All deficiencies noted were directed to the supplier, designer, or installer as appropriate for correction.

Upon the completion of the commissioning tests, and the correction of deficiencies noted, the equipment was accepted for energization tests.

(b) Energization tests

Upon satisfactory completion of the commissioning tests the equipment was test energized at rated voltage and functionally tested to ensure that the installation would provide proper, safe, and reliable operation. Upon completion of the energization tests, and the satisfactory

correction of deficiencies noted, the equipment was accepted for entry into commercial service.

2.3 Test Standards

All tests were performed in accordance with manufacturer's instructions and accepted industry practices. The Canadian Electrical Association Commissioning Guide for Electrical Apparatus, Volumes I and II, served as a useful reference.

2.4 Organization - Testing and Commissioning

All testing and commissioning was performed under the direct supervision and to the satisfaction of B.C. Railway's Commissioning Engineer. Outside test agencies and resources were utilized as required.

The responsibilities of the Commissioning Engineer included:

(a) preparation of commissioning and start-up schedules.

(b) preparation and/or approval of all commissioning procedures.

(c) supervision and/or witnessing of all tests performed.

(d) review of all test results.

(e) preparation of deficiency lists.

(f) acceptance of all equipment from the supplier or installation contractor for Energization Tests. For the purposes of the Energization Tests, the Commissioning Engineer was the Operating Authority.

(g) upon completion of Energization Tests, the Commissioning Engineer transferred Operating Authority to the Operating Department complete with a list of outstanding deficiencies and applicable operating restrictions.

3. COMMISSIONING TESTS

3.1 230/50 kV Substation

All major equipment (power transformers, instrument transformers, circuit breakers, disconnect switches, protection and control panels) was erected and installed under the direction of the manufacturer's representatives.

The installation contractor was contractually responsible to perform equipment and functional tests for all substation equipment (except for the SCADA system). All tests were performed under the direction of B.C. Railway's Commissioning Engineer.

The following individual equipment commissioning tests were performed prior acceptance for Energization Tests (for test results see Appendix B).

3.1.1 250/50 KV Power Transformers (25/33 MVA ONAN, ONAF)

(a) Oil sampling

The transformers were received on site oil filled. All top up oil was tested to ASTM standard D-877 for dielectric breakdown prior to use. All oil not meeting the specified +30 kV dielectric strength was rejected.

A bottom oil sample was taken 24 hours after top up for dielectric testing to ASTM D-877. Oil samples were forwarded for laboratory analysis regarding:

i)	dielectric	(D-877)
ii)	water content	(D-1533)
iii)	colour	(D-1500)
iv)	acidity	(D-664)
v)	power factor	(D-924)
vi)	dissolved gases	(D-117)
vii)	inhibited content	(D-2668)
viii)	interfacial tension	(D-971)

(b) Winding insulation resistance (megger).

(c) Winding insulation and bushing power factor (Doble).

(d) Winding resistance (all taps).

(e) Ratio (all taps).

(f) Polarity.

(g) Bushing current transformers:

i) D.C. resistance.

ii) ratio.

iii) polarity.

iv) winding insulation resistance (megger).

(h) Core insulation (megger).

(i) Gas accumulation relay calibration and function test.

(h) winding hot spot indicator calibration.

3.1.2 230 kV Circuit Breaker (ASEA type HLR 245, minimum oil, 3 phase)

(a) Oil analysis as per section 3.1.1 (a).

(b) Measure grading capacitor.

(c) Insulation power factor (Doble).

(d) Main contact resistance (ductor).

(e) Timing tests (primary and backup).

(f) Minimum coil operating voltage and coil resistance.

(g) Trip free and antipump.

(h) Kirk key and electrical interlocking.

Tests (e), (f), and (g) were performed by ASEA during erection. These tests were witnessed and accepted by B.C. Rail's Commissioning Engineer. As a result, these tests were not repeated by the testing agency.

3.1.3 50 kV Circuit Breaker (ASEA type HPL 145, single phase, SF_6)

All tests detailed in 3.1.2 were performed with the exception of oil analysis and grading capacitory measurements.

3.1.4 Voltage Instrument Transformers

(a) Oil analysis as per 3.1.1 (a).

(b) Winding insulation resistance (megger):

i) high voltage winding - low voltage winding.

ii) high voltage winding - case.

iii) low voltage winding - case.

(c) Insulation power factor (Doble):

i) high voltage winding - case.

ii) high voltage winding - low voltage winding.

(d) Ratio (all windings).

(e) Polarity.

3.1.5 Current Instrument Transformers

(a) Oil analysis as per 3.1.1 (a).

(b) Winding insulation resistance (megger):

i) high voltage winding - low voltage winding.

ii) low voltage winding - ground.

(c) Insulation power factor (Doble).

(d) Polarity.

(e) Ratio (all windings).

(f) Secondary winding D.C. resistance.

(g) Magnetization curve (CT saturation).

3.1.6 Lightning (Surge) Arrestors

(a) Insulation power factor (Doble).

(b) Where the lightning arrestor is isolated from ground and a counter is utilized, the insulation resistance was measured via megger.

3.1.7 Pre-insertion Resistor

(a) Insulation resistance (megger).

(b) Resistance.

3.1.8 Air Core Reactor

(a) Winding insulation resistance (megger).

(b) Winding d.c. resistance.

(c) Reactance (via low voltage injection).

3.1.9 Shunt Capacitor

(a) High pot test (50 kV d.c. for 5 min.).

(b) Capacitance measurements and balance between banks.

3.1.10 Air Break Disconnect Switches

(a) Contact resistance measurements (ductor).

3.1.11 Protection and Control Panels

Due to time constraints, the protection and control panel manufacturer performed the "Factory" acceptance test on site. These tests included:

(a) function testing of the protection and control schemes as installed. The field wiring was isolated at the test blocks.

(b) calibrating and testing all protective relays, meters, etc., as outlined by the manufacturer.

These tests were witnessed by B.C. Rail's Commissioning Engineer and were accepted as part of the commissioning tests (see Appendix C).

3.1.12 Ground Mat Resistance and Integrity

The substation ground mat resistance was measured using the Fall-of-Potential Method. The test was performed twice, approximately one month apart. Each test involved a measurement of B.C. Rail's ground mat isolated from B.C. Hydro substation ground mat and a measurement with the mats connected. The integrity of each equipment ground riser was proven via current injection.

3.1.13 Functional Testing

Upon satisfactory completion of individual equipment tests as outlined in sections 3.1.1 - 3.1.12 inclusive, the substation was functional tested as an integrated system.

All control, metering, protection, and alarm functions were proven via secondary injection or simulation at the initiating device.

3.1.14 Substation Deficiencies

During construction, inspection, and the commissioning tests 3.1.1 - 3.1.12, deficiencies were noted. These deficiencies fell into two categories:

(a) major deficiencies - these deficiencies were of a serious nature and required remedial action before the equipment could be energized.

(b) minor deficiencies - these deficiencies were of a less serious nature and the equipment could be safely energized.

3.1.15 Substation Energization

Upon satisfactory completion of commissioning tests 3.1.1 - 3.1.13, and correction of major deficiencies noted in 3.1.14, the substation equipment was accepted for energization.

On 07 Nov, 1983, the substation was energized without incident.

3.2 50 kV Feeder Line

A detailed visual inspection was conducted prior to energization. No commissioning tests were deemed necessary.

3.3 Catenary System

3.3.1 The catenary system was energized based on a detailed visual inspection. Low voltage current injection was performed from the substation to prove the integrity of the ground return prior to energizing.

3.3.2 The following catenary system tests are scheduled to be conducted in the early summer of 1984:

(a) Rail potential and potential gradient.

(b) Catenary capacitance.

(c) Catenary impedance.

(d) Catenary current distribution.

Details of these tests will be included in the final report.

3.4 Series Capacitor Station

The Series Capacitor Station was a "turn-key" contract. All testing and commissioning was performed under the direction of the manufacturer's representative and was to the satisfaction of B.C. Railway's Commissioning Engineer (see Appendix D).

3.5 Harmonic Filter Station

The harmonic filter station consists of an RC high pass (7th harmonic and above) and a LC filter tuned to the 5th harmonic.

The following individual equipment tests were performed:

3.5.1 Vacuum Breaker

(a) Contact resistance.

(b) High pot (30 kv a.c.)

(c) Coil operation to 70% of rated voltage.

3.5.2 Current Instrument Transformers

(a) Winding insulation resistance (megger).

(b) Insulation power factor (Doble).

(c) Polarity.

(d) Ratio.

(e) D.C. resistance.

3.5.3 5th Harmonic Reactor

(a) Winding insulation resistance.

(b) Winding resistance.

(c) Winding reactance (via low level injection).

3.5.4 Shunt Capacitor

(a) High pot.

(b) Capacitance measurement and bank balance.

3.5.5 Air Break Disconnect Switch

(a) Contact resistance.

(b) Timing test.

3.5.6 Protection and Control Schemes

(a) Calibration setting and testing of protective relays.

(b) Functional test of entire protection, metering, and alarm functions via primary injection.

(Please refer to Appendix F for test results.)

3.6 Supervisory and Control System (SCADA)

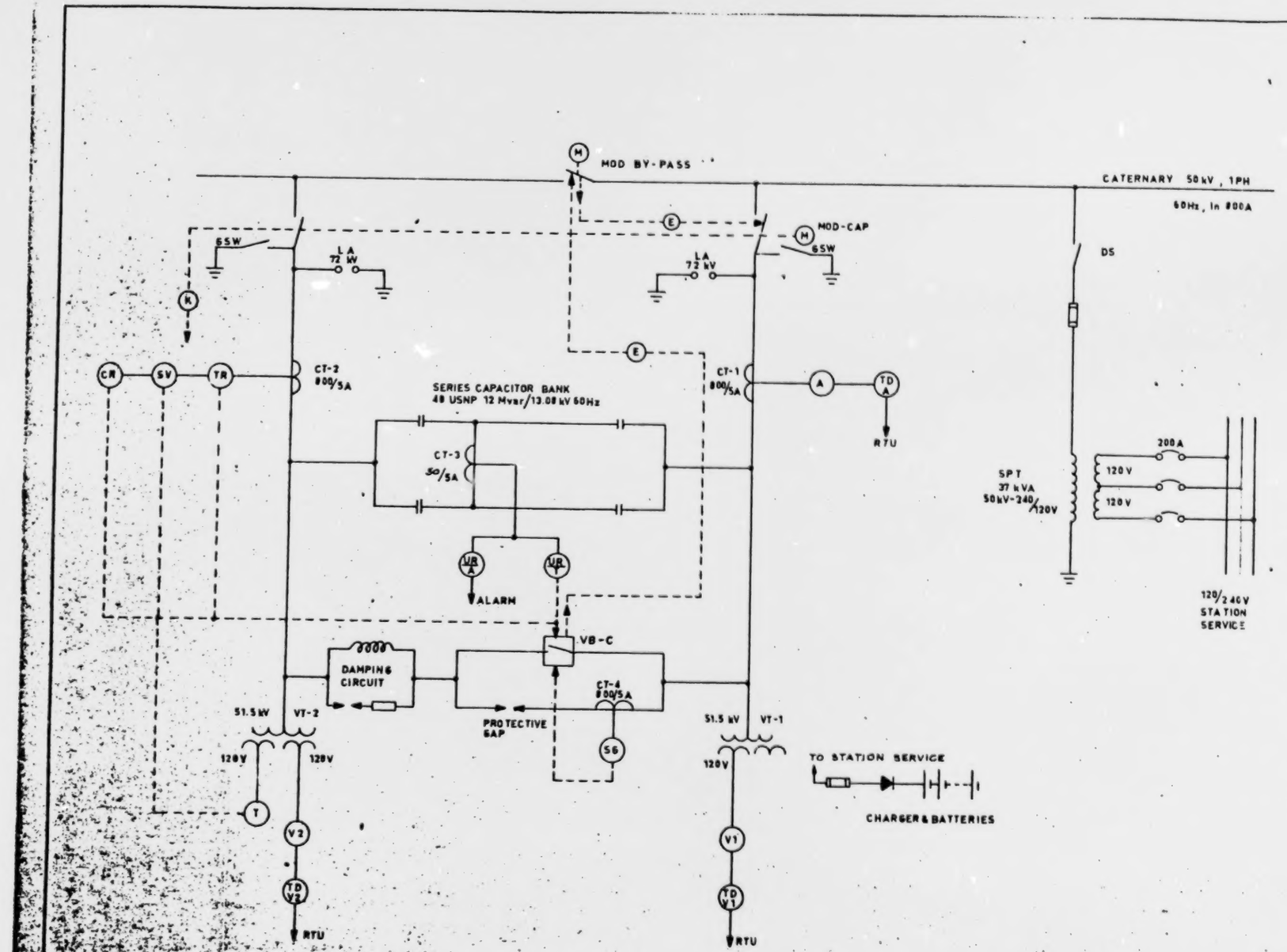
The complete Supervisory and Control system has not been commissioned at this time, and thus is not included in this interim report.

3.7 Trackside Power Supply

The trackside power supplies have not been commissioned at this time, and thus are not included in this interim report.

APPENDIX A

ELECTRIFICATION - ONE LINE DIAGRAMS



DESIGNATIONS

VB	Vacuum circuit breaker
MOD	Motor operated disconnect
DS	Disconnect switch
GSW	Ground switch
LA	Surge arrestor
CT	Current transformer
VT	Voltage transformer
SPT	Service power transformer
E	Electrical interlock
K	Kirk-key interlock
A	Ampere meter
V	Voltage meter
TDA	Current transducer for telemetering
TDV	Voltage transducer for telemetering
SG	Spark gap relay
TR	Overcurrent relay
SV	Sustained overvoltage relay
CR	Maximum current relay
UR/A	Unbalance protection relay, alarm
UR	Unbalance protection relay, trip
RTU	Remote terminal unit
T	Delay timer

AS BUILT 24/05/84

SYMBOL	REVISIONS	DATE	DRAWN	APPR
REF.				

NOKIA ENGINEERING

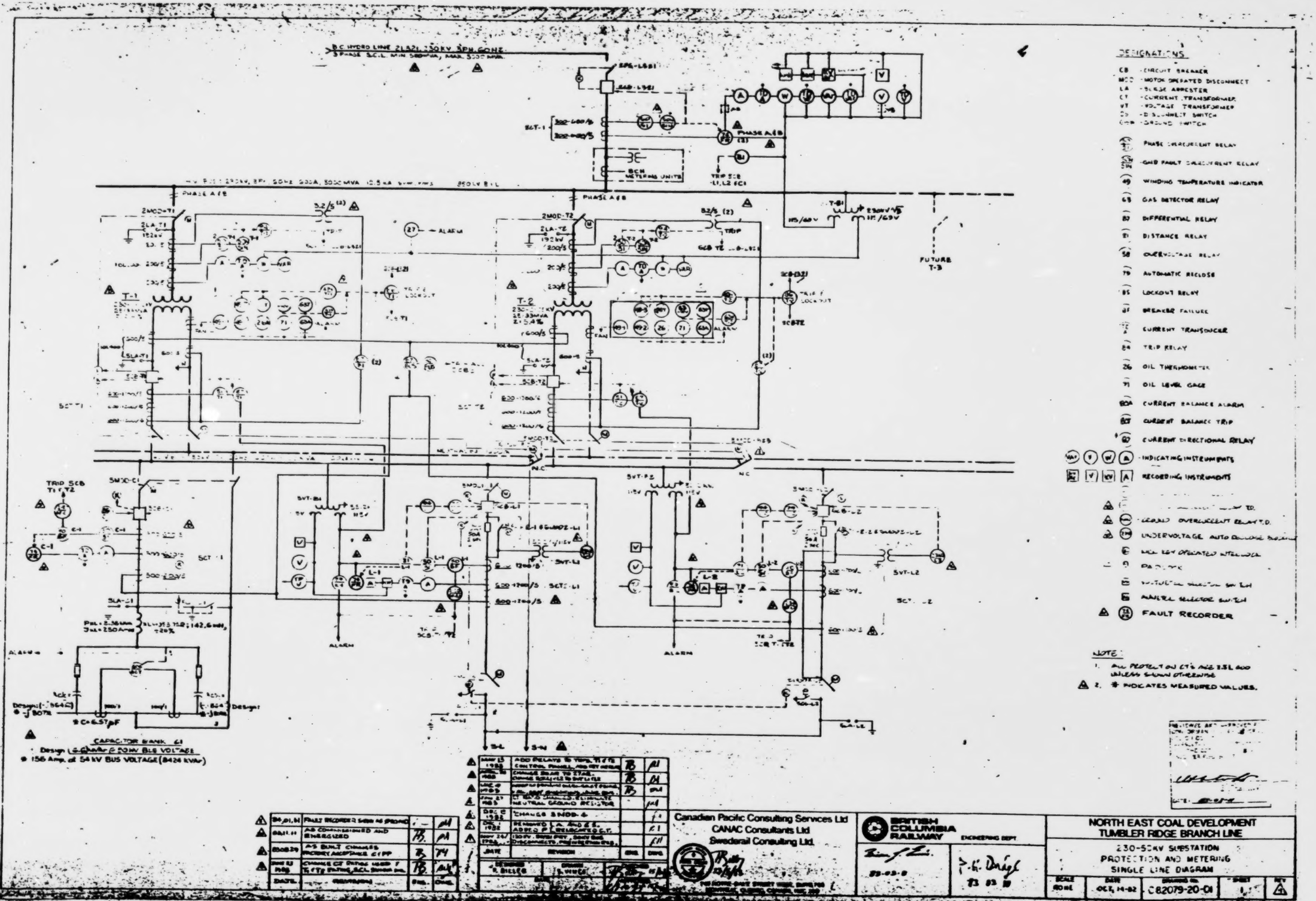
TITLE SERIES CAPACITOR STATION
SINGLE LINE DIAGRAM

SCALE

	DATE	NAME
DRN.	26.4.83	AV
APPR	28/4/83	MG

DRG. E2-431
A3/15-23314

A3/15-23314



DESIGNATIONS

- CB - CIRCUIT BREAKER
- MOD - MOTOR OPERATED DISCONNECT
- LA - SURGE ARRESTER
- CT - CURRENT TRANSFORMER
- VT - VOLTAGE TRANSFORMER
- DS - D.S. DISCONNECT SWITCH
- GND - GROUND SWITCH
- (67) PHASE OVERCURRENT DIRECTIONAL RELAY
- (67N) GND FAULT OVERCURRENT DIRECTIONAL RELAY
- (49) WINDING TEMPERATURE INDICATOR
- (63) GAS DETECTOR RELAY
- ( ) DIFFERENTIAL RELAY
- (21) DISTANCE RELAY
- (59) OVERVOLTAGE RELAY
- (79) AUTOMATIC RECLOSE
- (86) LOCKOUT RELAY
- (BF) BREAKER FAILURE
- CT A - CURRENT TRANSDUCER
- (94) TRIP RELAY
- (26) OIL THERMOMETER
- (71) OIL LEVEL GAGE
- (50A) CURRENT BALANCE ALARM
- (50T) CURRENT BALANCE TRIP
- (67) CURRENT DIRECTIONAL RELAY
- (MAT) (V) (W) (A) INDICATING INSTRUMENTS
- (W) (V) (kW) (A) RECORDING INSTRUMENTS
- (A) (50) GROUND OVERCURRENT RELAY T.D.
- (27) UNDERVOLTAGE AUTO RECLOSE INTERLOCK
- (86) MULTI-COIL LOCK-OUT OPERATED INTERLOCK
- (52) PARALLEL
- (43) MANUAL TRANSFER SWITCH
- (43) MANUAL SELECTOR SWITCH
- (21/FR) FAULT RECORDER

NOTE:

1. ALL PROTECTION CT'S ARE 2.5L 400 UNLESS SHOWN OTHERWISE
2. * INDICATES MEASURED VALUES.

84, 91, 94	FAULT RECORDER SIGN AS BUILT	—	AH
84.11.11	AS COMMISSIONED AND ENERGIZED	BB	AH
85.08.29	AS BUILT CHANGES PROTECT ACCEPTANCE C.I.P.P.	BB	TH
86.12.10	CHANGE CT RATIO USED FOR 51/TR RATING, ACCL. SCHEME ETC.	BB	AH
DATE	REVISION	ENG.	DWG.

Canadian Pacific Consulting Services Ltd
CANAC Consultants Ltd
Swedenrail Consulting Ltd.

BRITISH COLUMBIA RAILWAY ENGINEERING DEPT.

NORTH EAST COAL DEVELOPMENT
TUMBLER RIDGE BRANCH LINE
230-50kV SUBSTATION
PROTECTION AND METERING
SINGLE LINE DIAGRAM

SCALE	DATE	DRAWING NO.	SHEET	REV.
NONE	OCT. 14-82	C82079-20-01	1	4

APPENDIX B

230/50 KV SUBSTATION TEST RESULTS

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

I N D E X

SECTION I	-	230/50 KV SWITCH YARD
SECTION II	-	230 & 50 KV BUS
SECTION III	-	LIGHTNING ARRESTORS
SECTION IV	-	230 & 50 KV TRANSFORMERS
SECTION V	-	230 & 50 KV BREAKERS
SECTION VI	-	230 & 50 KV CURRENT TRANSFORMERS
SECTION VII	-	230 & 50 KV VOLTAGE TRANSFORMERS
SECTION VIII	-	50 KV RESISTORS
SECTION IX	-	CAPACITOR BANK
SECTION X	-	REACTOR
SECTION XI	-	TRANSFORMER GAS RELAYS
SECTION XII	-	BATTERY CHARGERS & BATTERIES
SECTION XIII	-	GROUND GRID CONNECTIONS
SECTION XIV	-	PROTECTION & CONTROL
SECTION XV	-	ENERGIZATION
SECTION XVI	-	SCADA SYSTEM
SECTION XVII	-	GROUND MAT RESISTANCE
SECTION XVIII	-	OIL LEVELS & GENERAL EQUIPMENT INSPECTION
SECTION XIX	-	GENERAL : Deficiencies : Comments & Recommendations
APPENDIX 'A'	-	DOBLE TEST SHEETS
APPENDIX 'B'	-	OIL ANALYSIS SHEETS

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

"a"

SECTION I

230/50 KV SWITCH YARD

The following is a summary of contact resistance measurements taken in the 230/50 KV Switch yard.

(A) 230 KV Disconnects:

1) 2DS-L321 Kearney - AØ = 28 micro ohms
BØ = 29 micro ohms
CØ = 31 micro ohms

2) 2MOD-T1 Kearney, 70 KA, Serial No. 7283 - AØ = 28 micro ohms
BØ = 60 micro ohms

3) 2MOD-T2 Kearney, 70 KA, Serial No. 7282 - AØ = 80 micro ohms
BØ = 80 micro ohms

(B) 230 KV Breaker:

ASEA, Serial No. 7346-062, Gas Pressure - 0.45 K Pa,
AØ = 110 micro ohms
BØ = 100 micro ohms
CØ = 105 micro ohms

(C) 50 KV Disconnect:

1) 5MOD-T1, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 27 micro ohms
Neut. = 25 micro ohms

2) 5MOD-T2, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 20 micro ohms
Neut. = 21 micro ohms

3) 5MOD-B2, KMT-9A, 2000A Kearney, 72.5 KV, Phase = 12 micro ohms

4) 5MOD-B23, KMT-9A, 2000A Kearney, 72.5 KV, Phase = 14 micro ohms

5) 5MOD1-L1, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 22 micro ohms

6) 5MOD2-L1, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 22 micro ohms

7) 5MOD1-L2, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 25 micro ohms

8) 5MOD1-L2, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 21 micro ohms

9) 5MOD2-L1, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 18 micro ohms

10) 5MOD3-L2, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 21 micro ohms

11) 5MOD-C1, KMT-9A, 1200A Kearney, 72.5 KV, Phase = 19 micro ohms
Neut. = 20 micro ohms

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

"b"

(D) 50 KV Ground Switches:

1) 5GS-L1 = 40 micro ohms
2) 5GS-L2 = 45 micro ohms
3) 5GS-C1 = 42 micro ohms - Phase
   " = 42 micro ohms - Neut.

(E) 50 KV Breakers:

1) 5CB-T1, ASEA, BLG 352, Gas Pressure - 0.45K Pa, Serial No. 7336027, 2500A, Type HPL/145/2501,
   Phase = 40 micro ohms

2) 5CB-T2, ASEA, BLG 352, Gas Pressure - 0.45K Pa, Serial No. 7336018,
   Phase = 53 micro ohms

3) 5CB-L1, ASEA, BLG 352, Gas Pressure - 0.45K Pa, Serial No. 7336020, 2500A, Type HLP/145/2501,
   Phase = 51 micro ohms

4) 5CB-L2, ASEA, BLG 352, Gas Pressure - 0.45K Pa, Serial No. 7336019, 2500A, Type HPL/145/2501,
   Phase = 55 micro ohms

5) 5CB-C1, ASEA, BLG 352, Gas Pressure - 0.45K Pa, Serial No. 7336026, 2500A, Type HPL/145/2501,
   Phase = 47 micro ohms.

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION II

230 & 50 KV BUS

Bus Insulation Results (@ 5 KV DC):

All 230 KV and 50 KV Bus and equipment measured infinity (100K meg ohms plus), when isolated from ground, lightning arrestors disconnected and surge suppressors isolated.

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION III

LIGHTNING ARRESTORS

All listed lightning arrestors having isolated bases and cable to counters were isulation resistance tested to 5 KV DC and read infinity (100K meg ohms plus).

2LA-T2
5LA-L1
5LA-L2

Please refer to Doble test data sheets for test results (Appendix 'A').

NOTE : 5LA-C1 (no counter) base was not grounded at the time of test. United Power personnel were informed.

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

"a"

SECTION IV

T2

230/50 KV TRANSFORMER

(A) Oiling:

Oil top up was performed under the supervision of Canadian General Electric.

Each barrel was tested for dielectric breakdown (+30 KV, D-877). Of the barrels tested, one barrel was scrapped for low dielectric.

A bottom samples was taken and tested 24 hours after top up and read 43.8 KV.

Oil samples were also taken for Lab analysis. Results of the oil analysis have been tabulated by B.C. Hydro. Please refer to Appendix 'B'.enclosed.

(B) Insulation:

Please refer to attached test sheets.

(C) Ratio & Polarity:

Please refer to attached test sheets.

(D) Winding Resistance:

Please refer to attached test sheets.

(E) Core Insulation:

Please refer to attached test sheets.

(F) Current Transformers:

Please refer to attached test sheets.

(G) Doble Testing:

Please refer to Appendix 'A'.

(H) Gas Relay Test:

By B.C. Hydro; please refer to Section XI.

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

"b"

(I) Inspection & Tests:

1) Oil level indicator and wiring - ok
2) Liquid temperature indicator and wiring - ok
3) Winding hot spot indicator and wiring - ok
   5A for 5 minutes = 23°C - ok

DRC/pj

"OUR ONLY BUSINESS IS SERVICE"

CHIPPENDALE ELECTRICAL SERVICES LTD.

TRANSFORMER TEST AND INSPECTION REPORT

Customer United Power	Job No.	Location BCR Sub		Date Sept. 29/83
Identification No.	Manufacturer CGE	Voltage (prl) 230kV	Voltage (sec) 5/12.5kV	Type ONAN/ONAF
Sr. No. 289579	Vector Dia. SINGLE PHASE.	Core Grd. 1000MΩ IR @ 500Vdc	HI-low and grd 1 min: 3900 10 " : 8300 IR @ 5 k Vdc	Low-high and grd 1 min: 6000 10 min: 20000 IR @ 5k Vdc
KVA 81.25/89.2 MUA				High-low IR @ ____ Vdc
%Imp				

% Ratio = $\frac{Lv}{Hv} \times 100$

Measured % Ratio — Winding Resistance

Tap Pos.	Voltage	Calculated % Ratio	$H_1 - H_2$ / $X_1 - X_4$				HI-H2	X1-K2
1	241500		21.180				1.832	30.65 @ mΩ
2	235750		21.682				1.793	X3-X4
3	230000		22.212				1.751	30.68 @ mΩ
4	224250		22.783				1.714	
5	218500		23.383.				1.668	

@ ON 50mΩ scale

Comments Insulation Resistance Test(s) at 5°C

Inspected by R. Gould

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

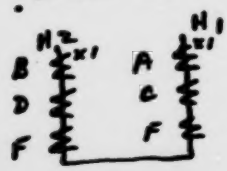
Customer U.P. - B C R
Manufacture C G E.
Type 230/50 KV

C.B., Transformer, or Line Position T2
C.B., or Transformer Serial No. 289579
Job No. C-

Supply Primary	Supply Secondary Volts	Supply Secondary Amps	Ratio Primary Secondary Lead	Ratio Meas. Volts Amps	Ratio Calc. Volts Amps	Name Plate Ratio	Exc. Amps Res.	Polarity (Via Load Flow) Connection Batt	Polarity (Via Load Flow) Connection Meter	Polarity (Via Load Flow) Met. Defl.	Serial Number & Position
230 KV CTS			(H1 - H2)								'A'
'A' CTS	400V		1.0V	1.002	1.0V	200/5	0.9Ω				'B'
'B' CTS	40.0V		1.0V	1.001	1.0V	200/5	0.9Ω				'C'
'C' CTS	40.0V		1.0V	1.003	1.0V	200/5	0.9Ω				'D'
'D' CTS	40.0V		1.0V	1.003	1.0V	200/5	0.9Ω				'E'
'E' CTS	40.0V		1.0V	1.001	1.0V	200/5	0.9Ω				'F'
'F' CTS	40.0V		1.0V	1.005	1.0V	200/5	0.9Ω				
50 KV CTS			(X1 - X4)								
'G' CTS	120V		1.0V	1.007	1.0V	600/5	0.5Ω	X1 - X4	X1 - X2	+	
'H' CTS	120V		1.0V	1.004	1.0V	600/5	0.5Ω	X1 - X4	X1 - X2	+	

INSULATION: SEC INS. 230 KV & 50KV CTS ALL (10K + MΩ) AT 500 VDC

REMARKS:



TESTED BY: D CHIPPENDALE CET

DATE: OCT 6/83

CHIPPENDALE ELECTRICAL SERVICES LTD.

Date: December 20, 1983

To: United Power Limited

Re: B.C. Rail Substation

230/50 KV TRANSFORMER T1

1) Oiling:

Oil top up was performed under the supervision of Canadian General Electric.

Each barrel was tested for dielectric breakdown (+30 KV, D-877).

A bottom sample was taken and tested 24 hours after top up and read 42.0 KV.

Oil samples were also taken for Lab analysis. Results of the oil analysis are enclosed. Gas-in-oil, inhibitor content, and power factor analysis will follow under separate cover.

2) Insulation:

Please refer to attached test sheets.

3) Ratio & Polarity:

Please refer to attached test sheets.

4) Winding Resistance:

Please refer to attached test sheets.

5) Core Insulation:

Please refer to attached test sheets.

6) Current Transformer:

Please refer to attached test sheets.

7) Gas Relay Test:

Please refer to attached test sheet.

.....2

CHIPPENDALE ELECTRICAL SERVICES LTD.

Date: December 20, 1983

To: United Power Limited

Re: B.C. Rail Substation

---

8) Inspection & Tests:

(a) oil level indicator and wiring - ok.

(b) liquid temperature indicator and wiring - ok.

(c) Winding hot spot indicator and wiring - ok.

5A for 5 minutes = $0^{o}C$ - ok.

RWGould/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

3252 BETA AVENUE, BURNABY, B.C. V5G 4K4

TRANSFORMER TEST AND INSPECTION REPORT

Customer: United Power		Job No.	Location: BCR Sub. Tumbler Ridge		Date: Dec 20/83
Identification No.: T1	Manufacturer: CGE		Voltage (prl): 230kV	Voltage (sec): 50kV	Type: ONAN/ONAF
Sr. No.: 298578	Vector Dia.	Core Grd.	Hi-low and grd	Low-high and grd	High-low
MVA: 31.25/39.2		8000	50000	30000	40000
%Imp: 5.4	Single Phase	IR @1000Vdc	IR @ 5000 Vdc	IR @ 5000 Vdc	IR @ 5000 Vdc

% Ratio = $\frac{Lv}{Hv} \times 100$			Measured % Ratio				
Tap Pos.	Voltage	Calculated % Ratio	$H_1 - H_2$ / $X_1 - X_4$	Winding Resistance $H_1 - H_2$			
1	241500	21.220	21.195	1.624 Ω			
2	235750	21.740	21.686	1.592 Ω			
3	230000	22.280	22.231	1.549 Ω			
4	224250	22.850	22.797	1.494 Ω			
5	218500	23.460	23.390	1.451 Ω			

Comments: Winding Resistance $X_1 - X_4$ = 54.3 mΩ

Insulation and Winding Resistance measured @ -20° to -30°C

Inspected by R Gould

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Customer United Power
Manufacture CGE
Type

C.B., Transformer, or Line Position T1
C.B., or Transformer Serial No. 289578
Job No. C-

Ratio							Polarity			Serial Number & Position
Supply		Primary Secondary Lead	Meas. Volts Amps	Calc. Volts Amps	Name Plate Ratio	Exc. Amps Res.	Connection		Met. Defl	
Primary Secondary	Volts Amps						Batt	Meter		
230kV CTs		H_1-H_2								
A	40.0	1.0V	1.00V	1.0V	200/5	0.3Ω	H_1-H_2	X_1-X_2	+	A
B	40.0	1.0V	1.01V	1.0V		0.3Ω	H_2-H_1	X_1-X_2	+	B
C	40.0	1.0V	1.00V	1.0V		0.3Ω	H_1-H_2	X_1-X_2	+	C
D	40.0	1.0V	1.00V	1.0V		0.3Ω	H_2-H_1	X_1-X_2	+	D
E	40.0	1.0V	1.01V	1.0V		0.3Ω	H_1-H_2	X_1-X_2	+	E
F	40.0	1.0V	1.01V	1.0V	200/5	0.3Ω	H_2-H_1	X_1-X_2	+	F
50kV C.T.s		X_1-X_4								
G	120V	1.0V	1.00V	1.0V	600/5	0.4	X_1-X_4	X_1-X_2	+	
H	120V	1.0V	1.00V	1.0V	600/5	0.4	X_1-X_4	X_1-X_2	+	

Insulation: All CTs 10kMΩ + @500Vdc

Remarks:

Tested By: R. Gould

Date: Dec 20/83

CHIPPENDALE ELECTRICAL SERVICES LTD.

Date: December 20, 1983

To: United Power Limited

Re: B.C. Rail Substation

C.T. SATURATION TESTS:

T1 230 KV C.T.s : 200/5A 10L200 :

V =	50	100	150	175	200
AX1 - AX2	0.25	0.42	0.58	0.72	0.87
BX1 - BX2	0.29	0.45	0.62	0.73	0.86
CX1 - CX2	0.28	0.44	0.61	0.71	0.86
DX1 - DX2	0.28	0.45	0.61	0.71	0.83
EX1 - EX2	0.29	0.45	0.62	0.71	0.86
FX1 - FX2	0.27	0.44	0.61	0.71	0.85

T1 50 KV C.T.s : 600/5A 10L400 :

V =	100	200	300	400	450	500
GX1 - GX2	0.5	0.86	0.123	0.198	0.298	0.56
HX1 - HX2	0.46	0.79	0.114	0.178	0.276	0.53

RWGould/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

3252 BETA AVENUE, BURNABY, B.C. V5G 4K4

OIL TESTING REPORT

Customer: United Power Ltd

Date: Jan. 3/84

Location: BCR Substation TI S/N 289578

Job No.:

A. Dielectric Test : Breakdown voltage in KV.
This test measures the insulating ability of the oil and is very sensitive to impurities, especially water. Recommended 22KV minimum.

B. Interfacial Tension : Dynes per centimeter.
This test measures soluble impurities, soluble contaminents and deterioration products. Recommended 17 dy/cm minimum.

C. Neutralization Number : Milligrams of KOH/gm of oil.
This test measures the acids present in the oil, usually the result of oxidation. Recommended 0.25 mg of KOH maximum.

D. Colour : Hellige.
Recommended 3 maximum.

			A.	B.	C.	D.
Sample#	Customer Identification	Serial No	KV	IFT	Neut.	Colour
1	TI S/N 289578		37.4	35.0	0.02	C.75

Comments:
"Gas In Oil" analysis : to follow
Inhibitor content : "
Power Factor : "

Tested by R Gould

CHIPPENDALE ELECTRICAL SERVICES LTD.

Date: December 20, 1983

To: United Power Limited

Re: B.C. Rail Substation

T1 PROTECTION:

Device No.	
50/51 HV 50/51 N	Test C.T. wiring from C.T. secondary terminals through 50/51 HV and 50/51 N relays.
87/T-1	Test C.T. wiring from C.T. secondary terminals through test block on both 230 KV and 50 KV.
Metering	Test C.T. wiring from C.T. secondary terminals through test block.
63T	Proved trip to device 63X and 86T1 from transformer terminals.
63A	Proved alarm to terminal blocks from transformer terminals.
63PRV	Proved trip to 63X and 86T-1 from transformer terminals.
49T	Proved trip to 49X and 86T-1 from transformer terminals.
49A	Proved alarm to panel terminals from transformer terminals.
26T	Proved trip to 49X and 86T-1 from transformer terminals.
26A	Proved alarm to panel terminal from transformer terminals.
71	Proved alarm to annunciator.

RWGould/pj

CHIPPENDALE ELECTRICAL SERVICES LTD. (604) 291-9681

PROTECTIVE RELAY TEST & CALIBRATION DATA SHEET

DATE: Dec 19/83

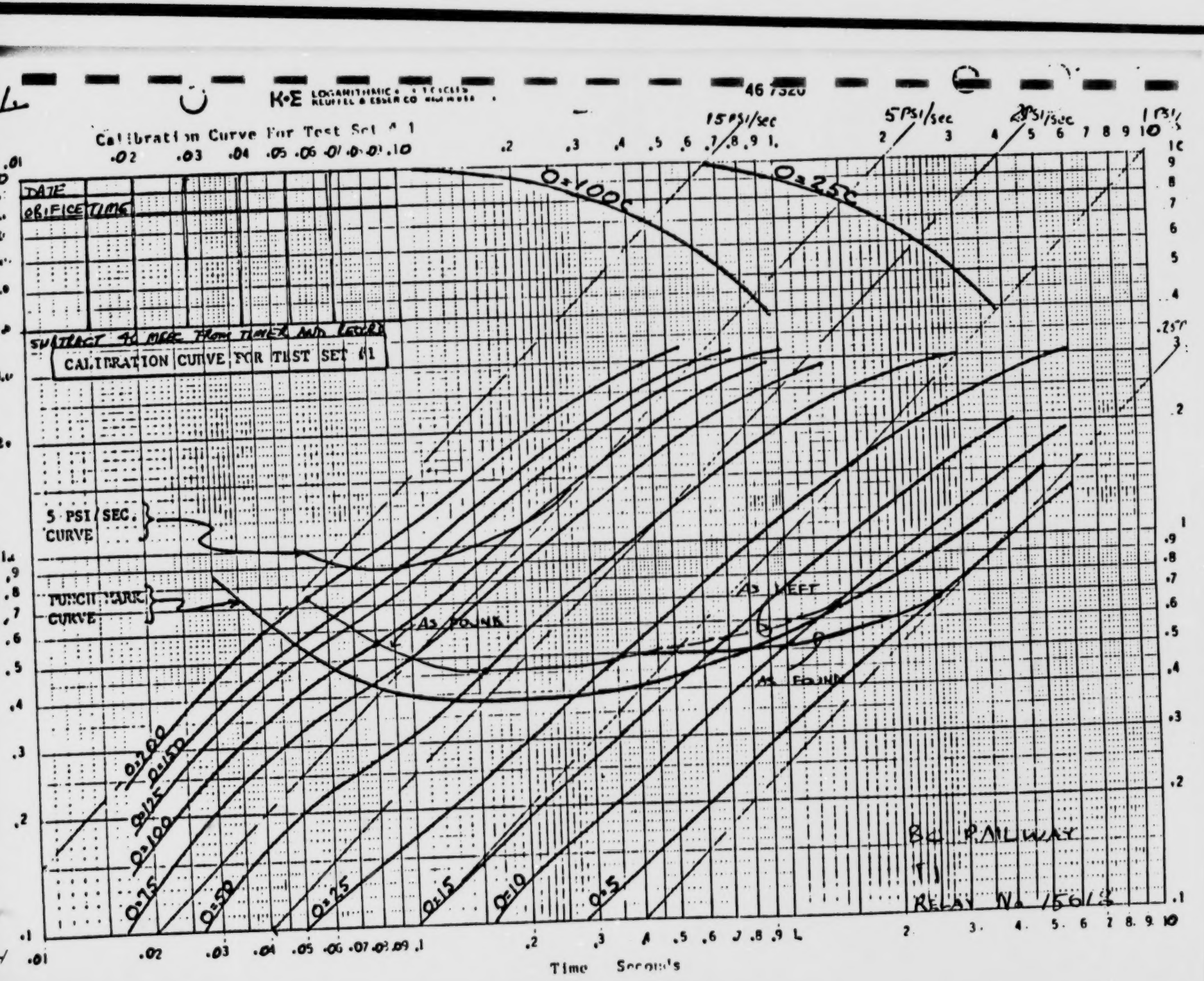
CUSTOMER: United Power SUBSTATION: P.C. Rail Tumbler Ridge

JOB NO.:

RELAY			AS FOUND			AS LEFT			AS FOUND				AS LEFT						
PHASE	TYPE	MAN	TAP	T D	INST	TAP	T D	INST	P.U.	T	T	INST	P.U.	T	T	INST	TARGET	TARGET	
LOCATION 86T1																			
	VAJ	GEC	Coil P.U. @ 100Vdc latch			ok			contacts ok								ok		
			D.O. @ 86Vdc																
LOCATION																			
LOCATION																			

REPAIRS & COMMENTS

3252 Beta Avenue
Burnaby, [illegible] 4K[illegible]


K•E LOGARITHMIC
46 7520
Calibration Curve For Test Set # 1
15 PSI/sec
5 PSI/sec
2 PSI/sec
1 PSI/
DATE
ORIFICE TIME
Q=100
Q=2.5
SUBTRACT To MAKE FROM TIMER AND LEVERS
CALIBRATION CURVE FOR TEST SET #1
5 PSI/SEC. CURVE
PUNCH MARK CURVE
AS FEET
AS FOUND
AS FOUND
Q=200
Q=150
Q=125
Q=100
Q=75
Q=50
Q=25
Q=15
Q=10
Q=5
B&O RAILWAY
RELAY No 1561
Time Seconds

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION V

230 & 50 KV BREAKERS

Breakers were erected and tested by ASEA. A copy of their report is attached. I have reviewed the results contained in this report and concure.

In addition, contact resistance and gas pressures have been recorded.

Oil samples were taken on the 230 KV breaker for lab analysis. (No extra oil was required).

Doble Tests : please refer to Appendix "A" for test results.

NOTE : On November 7th, a gas alarm appeared on 5CBL1 circuit breaker. The pressure reading was checked and found to be 0.36K Pa. B.C. Rail was notified.

DRC/pj

ASEA

VISIT REPORT NO. 72 B. LOFGREN

Visit to: Tumber Ridge, B.C.
B.C. Rail

Date: September 7-11, 1983

Copies to:

B.C. Rail	-	J. Popoff
ASEA Varennes	-	J.-P. Noiseux
ASEA Vancouver	-	F. DaCosta
ASEA Ludvika	-	U. Borg, LKKA
ASEA Ludvika	-	M. Valtonen, LFU

Present were:

B.C. Rail	-	J. Popoff
ASEA INC.	-	B. Lofgren
ASEA INC.	-	O. Albinsson

ACCOUNT OF VISIT:
To erect and commission one HLR 245/2502 E 2 and five HPL 145/2501.

SUBJECT A:
HLR 245/2502 E 2
Serial no. 7346 062
Order: L 2779-4010-001
BLG: 352C
Serial no. 7346 063

Found motor starter had been broken during transport. Had to be replaced. Interlocking bracket missing. One trip coil missing. Erection and commissioning according to ASEA specifications.

Test report: See Appendix A.

SUBJECT B:
HPL 145/2501
Serial no. 7336 019
Order no. L 2776.1047-001
BLG 352
Serial no. 7336 024

Erection and commissioning according to ASEA specifications.

Test report: See Appendix B.

SUBJECT C:
HPL 145/2501
Serial no. 7336 018
BLG 352
Serial no. 7336 023

VISIT REPORT NO. 72 (suite)

Erection and commissioning according to ASEA specifications.

Test report: See Appendix C

SUBJECT D: HPL 145/2501
Serial no. 7336 020
BLG 352
Serial no. 7336 025

Erection and commissioning according to ASEA specifications.

Test report: See Appendix D

SUBJECT E: HPL 145/2501
Serial no. 7336 021
BLG 352
Serial no. 7336 026

Found nameplate missing on operating mechanism. Erection and commissioning according to ASEA specifications.

Test report: See Appendix E.

SUBJECT F: HPL 145/2501
Serial no. 7336 022
BLG 352
Serial no. 7336 027

Found nameplate missing on operating mechanism. Erection and commissioning according to ASEA specifications.

Product information book referred to BLG 1002.
Operating mechanism supplied are BLG 352.
Functional values incorrect. They referred to C.B. type HPL with a BLG 1002 mechanism.

Cable installed on density gauge but not in operting mechanism as no hole saw was available. The contractor will do it later on.

ASEA INC.

B. Lofgren
83.09.20

5. A

Customer: B.C. RAIL TUMBLER RIDGE B.C.

C.B. Type: HLR 245/2502 E2 Serial No. 7346 062 Order No. L 2709 4010-001

Engineer: B. Lofgren Dept. CFD Date September 7, 1983

Pole	Closing time over pole ms	Opening time over pole ms	C/O Current path closed ms	t_1 ms	Contact travel mm	Control measure mm	Operation Mechanism Type: BLG 352C
A	119.9	27.8	40.7	100	482	236	Serial No. 7346 063
B	120.0	22.2	42.5				
C	119.0	22.6	43.3				

Pole	Limit Switch 5-6 Opening time ms	Difference 5-6/11-12 ms	Minimum Operating Voltage 125V-		Resistance μΩ	Counter Numbers	Thermostat Set to °C	Oil Dash Pot Check 20-30	≥ 40
A		2	70	30		.0	+10	7mm	
B									
C									

Pole	Element	Closing speed m/s	Opening speed m/s	Closing time ms	Opening time ms	Opening pressure MPa	Closing pressure MPa	Final pressure MPa	Note
	t_1 1)	8.6	7.5	119.9	22.8	0.65	0.45	0.5	A-Tid -45.1 mS B-Tid -40.2 mS
	2								
A	3								Over Travel - 20mm
left	4								
	5								
	6								
	t_1 1)			120.0	22.2	0.65	0.45	0.5	
	2								
B	3								
middle	4								
	5								
	6								
	t_1 1)			119.0	22.6	0.65	0.45	0.5	
	2								
C	3								
right	4								
	5								
	6								

D

Customer: B.C. RAIL TUMBLER RIDGE, B.C.

C.B. Type HPL 145/2501 Serial No. 7336 019 Order No. L 2776 1047-001

Engineer B. Lofgren Dept. CFQ Date September 7, 1983

Pole	Closing time over pole ms	Opening time over pole ms	C/O Current path closed ms	t_g ms	Contact travel mm	Control measure mm	Operation Mechanism Type BLG ...352..
A1	'88.6	33.2	60.4				Serial No. 7336 024
A2		34.5					
C							

Pole	Limit Switch 5-6 Opening time ms	Limit Switch difference 5-6/11-12 ms	Minimum Operating Voltage 125V- Close	Minimum Operating Voltage 125V- TR/TR2	Resistance mΩ	Counter Numbers	Thermostat Set to °C	Oil Dash Pot Check 20-30	Oil Dash Pot Check ≥ 40	
A		2	60	40 -60		0	+10	6.5mm		
B										
C										

Pole	Element	Closing speed m/s	Opening speed m/s	Closing time ms	Opening time ms	Opening pressure MPa	Closing pressure MPa	Final pressure MPa	Note
	1 1)							0.45	
	2								
A	3								
left	4								
	5								
	6								
	1 1)								
	2								
B	3								
middle	4								
	5								
	6								
	1 1)								
	2								
C	3								
right	4								
	5								
	6								

Customer: B.C. RAIL — TUMBLER RIDGE, B.C.

C.B. Type: HPL 145/2501 — Serial No. 7336 018 — Order No. L 2776 1047-001

Engineer: B. Lofgren — Dept. CPQ — Date: September 7, 1983

Pole	Closing time over pole ms	Opening time over pole ms	C/O Current path closed ms	t_1 ms	Contact travel mm	Control measure mm	Operation Mechanism Type BLG 352 .....
A 1	88.0	34.8	54.6				Serial No. 7336.023
R A2		34.3					
C							

Pole	Limit Switch 5-6 Opening time ms	Difference 5-6/11-12 ms	Minimum Operating Voltage 125V- Close	TR /TR2	Resistance μΩ	Counter Numbers	Thermostat Set to °C	Oil Dash Pot Check 20-30	≥ 40
A		2	70	45 -65		0	+10	7.0mm	
B									
C									

Pole	Element	Closing speed m/s	Opening speed m/s	Closing time ms	Opening time ms	Opening pressure MPa	Closing pressure MPa	Final pressure MPa	Note
	1 1)							0.45	
	2								
A	3								
left	4								
	5								
	6								
	1 1)								
	2								
B	3								
middle	4								
	5								
	6								
	1 1)								
	2								
C	3								
right	4								
	5								
	6								

D

Customer: B.C. RAIL — TUMBLER RIDGE, B.C.

C.B. Type: HPL 145/2501 — Serial No.: 7336 020 — Order No.: L 2776 1047.001

Engineer: B. Lofgren — Dept.: CFD — Date: September 7, 1983

Pole	Closing time over pole ms	Opening time over pole ms	C/O Current path closed ms	t_1 ms	Contact travel mm	Control measure mm	Operation Mechanism Type BLG 352
A 1	88.6	34.7	54.2				Serial No. 7336 025
A2		34.8					
C		..					

Pole	Limit Switch S-6 Opening time ms	Limit Switch Difference S-6/11-12 - ms	Minimum Operating Voltage 125V- Close /TR/TR2		Resistance μΩ	Counter Numbers	Thermostat Set to °C	Oil Dash Pot Check 20-30	Oil Dash Pot Check ≥ 40
A		2	70	65 -60		0	+10	6 mm	
B									
C									

Pole	Element	Closing speed m/s	Opening speed m/s	Closing time ms	Opening time ms	Opening pressure MPa	Closing pressure MPa	Final pressure MPa	Note
	1 1)							0.45	
	2								
A	3								
left	4								
	5								
	6								
	1 1)								
	2								
B	3								
middle	4								
	5								
	6								
	1 1)								
	2								
C	3								
right	4								
	5								
	6								

1) ... ... to be indicated on this element.

Customer: B.C. Rail TUMBLER RIDGE

C.B. Type: HPL 145/2501 Serial No. 7336 021 Order No. L 2776 1047-001

Engineer: B. Lofgren Dept. CFO Date September 7, 1983

Pole	Closing time over pole ms	Opening time over pole ms	C/O Current path closed ms	t_1 ms	Contact travel mm	Control measure mm
A 1	82.4	34.1	53.5			
B A2		33.1				
C						

Operation Mechanism Type BIG ...352.. Serial No. 7336 026

Pole	Limit Switch 5-6 Opening time ms	Limit Switch difference 5-6/11-12 ms	Minimum Operating Voltage 125V- Close /TR	/TR2	Resistance mΩ	Counter Numbers	Thermostat Set to °C	Oil Dash Pot Check 20-30	≥ 40
A		2	70	45 -60		0	+10	6.5mm	
B									
C									

Pole	Element	Closing speed m/s	Opening speed m/s	Closing time ms	Opening time ms	Opening pressure MPa	Closing pressure MPa	Final pressure MPa	Note
	1 1)							0.45	
	2								
A	3								
left	4								
	5								
	6								
	1 1)								
	2								
B	3								
middle	4								
	5								
	6								
	1 1)								
	2								
C	3								
right	4								
	5								
	6								

Customer: B.C. RAIL — TUMBLER RIDGE, B.C.

C.B. type: HPL 145/2501 — Serial No. 7336 022 — Order No. L 2776.1047-001

Engineer: B. Lofgren — Dept. CPD — Date: September 7, 1983

Pole	Closing time over pole ms	Opening time over pole ms	C/O Current path closed ms	t_1 ms	Contact travel mm	Control measure mm	Operation Mechanism Type BLE ..352.. Serial No. 7336.027
A 1	86.5	31.3	52.7				
A2		32.5					
C							

Pole	Limit Switch 5-6 Opening time ms	Difference 5-6/11-12 ms	Minimum Operating Voltage 125V- Close/ TR/ TR2		Resistance Ω	Counter Numbers	Thermostat Set to °C	Oil Dash Pot Check 20-30	≥ 40
A		2	70	55- 60		-0	+10	5.6mm	
B									
C									

Pole	Element	Closing speed m/s	Opening speed m/s	Closing time ms	Opening time ms	Opening pressure MPa	Blocking pressure MPa	Final pressure MPa	Note
	1 1)							0.45	
	2								
A	3								
left	4								
	5								
	6								
	1 1)								
	2								
B	3								
middle	4								
	5								
	6								
	1 1)								
	2								
C	3								
right	4								
	5								
	6								

1) to be indicated on this element.

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION VI

230 & 50 KV CURRENT TRANSFORMERS

The 230 KV current transformers were topped up with dielectric tested oil.

All C.T.s were Doble tested. Please refer to Appendix 'A' for test results.

All C.T.s have been tested for ratio, polarity, secondary winding resistance, and insulation resistance.

Oil samples have been taken for lab analysis. Please refer to Appendix 'B' for test results.

NOTE : CT-C1 was found to be physically located on the wrong steel structure. This was immediately corrected.

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

C.T. SATURATION TESTS

V =	100	200	300	400	500	550	
5CT-T1 : X1-X2	0.020	0.035	0.050	0.076	0.205	0.500	amps
(600-5) Y1-Y2	shorted - not used						
Z1-Z2	0.022	0.037	0.055	0.093	0.239	0.560	amps
5CT-T2 : X1-X2	0.020	0.034	0.050	0.075	0.200	0.560	amps
(600-5) Y1-Y2	shorted - not used						
Z1-Z2	0.020	0.032	0.046	0.070	0.210	0.560	amps
5CT-C1 : X1-X2	0.021	0.033	0.045	0.067	0.190	0.570	amps
(600-5) Y1-Y2	0.021	0.031	0.044	0.065	0.200	0.600	amps
Z1-Z2	0.022	0.033	0.046	0.070	0.160	0.570	amps
100/1 Thin Cable (ACJ)	0.001	0.002	0.003	0.004	0.005	0.006	amps
100/1 Thick Cable (ACL)	0.001	0.002	0.003	0.004	0.005	0.006	amps
5CT-L1 : X1-X2	0.026	0.042	0.061	0.101	0.265	0.600	amps
(600-5) Y1-Y2	0.028	0.037	0.048	0.069	0.210	0.590	amps
Z1-Z2	0.029	0.036	0.047	0.068	0.192	0.590	amps
5CT-L2 : X1-X2	0.029	0.042	0.064	0.112	0.305	0.600	amps
(600-5) Y1-Y2	0.026	0.036	0.047	0.068	0.190	0.556	amps
Z1-Z2	0.028	0.041	0.058	0.099	0.250	0.560	amps

A.Kay/pj

Continued.....

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

C.T. Saturation Tests Continued:

V =	50	100	150	200	300	400	550
AX1-AX2(300-5)	0.022	0.033	0.043	0.052	0.074	0.134	0.800
AY1-AY2(300-5)	0.024	0.036	0.046	0.056	0.070	0.130	0.800
BX1-BX2(300-5)	0.023	0.036	0.046	0.056	0.081	0.138	0.800
BY1-BY2(300-5)	0.022	0.037	0.046	0.057	0.082	0.137	0.800
CX1-CX2(300-5)	0.024	0.035	0.045	0.055	0.077	0.124	0.800
CY1-CY2(300-5)	0,025	0.035	0.046	0.055	0.076	0.128	0.800

T2 C.T.s : 200-5, 230KV :

V =	25	50	75	100	115
AX1-AX2	0.157	0.265	0.357	0.450	0.495
BX1-BX2	0.167	0.268	0.0357	0.444	0.496
CX1-CX2	0.187	0.295	0.385	0.447	0.526
DX1-DX2	0.157	0.268	0.355	0.444	0.491
EX1-EX2	0.170	0.274	0.359	0.444	0.495
FX1-FX2	0.157	0.267	0.355	0.437	0.485

600-5, 50 KV C.T.s :

V =	50	100	200	300	400	500	600
GX1-GX2	0.027	0.044	0.067	0.093	0.139	0.520	0.750
FX1-FX2	0.026	0.042	0.067	0.092	0.137	0.530	0.750

NOTE : 230KV C.T.s (A,B,C,D,E, & F) take fairly high current, but do not saturate at 115V.

A.Kay/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Customer U.P. BCR
Manufacture (W)
Type 230 KV

C.B., Transformer, or Line Position 2CT-1
C.B., or Transformer Serial No.
Job No. C-

Supply: Primary / Secondary	Volts / Amps	Ratio: Primary / Secondary Lead	Meas. Volts / Amps	Calc. Volts / Amps	Name Plate Ratio	Exc. Amps Res.	Polarity: Connection Batt	Polarity: Connection Meter	Met. Defl.	Serial Number & Position
Primary	Volts	H_1-H_2	1.002	1.0	300/5		H_1-H_4	X_1-X_2	+	LK50547
Secondary	Amps	1.0 V								
SR No	60V	1.0 V	1.001	1.0	300/5		H_1-H_4	Y_1-Y_2	+	Aϕ
LK50547	60V	(X_1-X_2	SEC.	WINDING	$R_{X_1X_2}$ = 0.5Ω					
Aϕ		Y_1-Y_2)	"	"	" = 0.4Ω					
600/300//5/5										
		H_1-H_2								
SR No	60V	1.0 V	1.000	1.0	300/5		H_1-H_4	X_1-X_2	+	LK50595
LK50595	60V	1.0 V	1.002	1.0	300/5		H_1-H_4	Y_1-Y_2	+	Bϕ
Aϕ		(X_1-X_2	SEC	WINDING	$R_{X_1X_2}$ = 0.4Ω					
600/300//5/5		Y_1-Y_2)	"	"	" = 0.4Ω					
		H_1-H_2								
SR No	60V	1.0 V	1.003	1.0	300/5		H_1-H_4	X_1-X_2	+	LK50596
LK50546	60V	1.0 V	1.002	1.0	300/5		H_1-H_4	Y_1-Y_2	+	Cϕ
Cϕ		(X_1-X_2	SEC	WINDING	$R_{X_1X_2}$ = 0.5Ω					
600/300//5/5		Y_1-Y_2)	"	"	" = 0.5Ω					

INSULATION: H_1-GRD 100K MΩ + 5KVDC } ALL 3ϕ's
L_0-GRD 10K MΩ + 500VDC }

REMARKS: NOTE: Bϕ - BLUE SEC WIRE LOOSE. - NUT ERODED THREADED.

TESTED BY: D. CHIPPENDALE C.E.

DATE: OCT 5/83.

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Customer UP - BCR

Manufacture (W)

Type OPC 69

C.B., Transformer, or Line Position SCT-T1

C.B., or Transformer Serial No.

Job No. C-

Ratio							Polarity			Serial Number & Position
Supply		Primary / Secondary Lead N_1-N_4	Meas. Volts / Amps	Calc. Volts / Amps	Name Plate Ratio	Exc. Amps / Res.	Connection Batt	Connection Meter	Met. Defl.	
Primary / Secondary	Volts / Amps									
X_1-X_2	120V	1.10 V	1.003	1.0	600/1200-5-5		H_1-H_4	x_1-x_2	+	LK50620
Y_1-Y_2	120V	1.0	0.997	1.0	"		"	y_1-y_2	+	
Z_1-Z_2	120V	1.0	1.001	1.0	"		"	z_1-z_2	+	
		X_1-X_2	SEC WINDING RES. = 0.5Ω							
		Y_1-Y_2	"	"	" = 0.5Ω					
		Z_1-Z_2	"	"	" = 0.5Ω					

Insulations: H_1-GRD - 100 KMΩ + 5KVDC
LO-GRD - 10 KMΩ + 500VDC.

Remarks:

Tested By: D. Chippindale CLE

Date: OCT 5/89.

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Name: UNITED POWER BCP
Manufacture: (W)
Type: OPC 69

C.B., Transformer, or Line Position: SCT-T2
C.B., or Transformer Serial No.: LK50619
Job No.: C-

Supply		Ratio					Polarity			Serial Number & Position
Primary / Secondary	Volts / Amps	Primary / Secondary Lead	Meas. Volts / Amps	Calc. Volts / Amps	Name Plate Ratio	Exc. Amps Res.	Connection: Batt	Connection: Meter	Met. Defl.	
X_1-X_2	120V	1.0V	1.003	1.00	1200/600/5/5/5		H_1-H_4	X_1-X_2	+	LK50619
Y_1-Y_2	120V	"	1.004	1.0	1200/600-5-5-5		H_1-H_4	Y_1-Y_2	+	
Z_1-Z_2	120V	"	1.001	1.0	"		H_1-H_4	Z_1-Z_2	+	
		X_1-X_2 SEC WINDING			Rx2 = 0.5Ω					
		Y_1-Y_2	"	"	" = 0.5Ω					
		Z_1-Z_2	"	"	" = 0.5Ω					

Insulations: Lo - Hi & GRD (500 V_{DC}) = 10K MΩ + (OK 1 MIN & 10 MIN)
Hi - Lo & GRD 5000 V_{DC} = 100K MΩ + (OK " ")

Remarks:

Tested By: D. Chippendale CET

Date: Oct 5/83

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Tomer UP - BCR
UFACTURE (W)
TYPE OPC 69

C.B., TRANSFORMER, OR LINE POSITION 5CT-L1
C.B., OR TRANSFORMER SERIAL NO. [illegible]
JOB NO. C-

RATIO							POLARITY			SERIAL NUMBER & POSITION
SUPPLY		PRIMARY SECONDARY LEAD	MEAS. VOLTS AMPS	CALC. VOLTS AMPS	NAME PLATE RATIO	EXC. AMPS RES.	CONNECTION		MET. DEFL.	
PRIMARY SECONDARY	VOLTS AMPS						BATT	METER		
$X_1 - X_4$	120V	1.0V	1.002	1	1200/600/5/5/5		$H_1 - H_2$	$X_1 - X_2$	+	LK 50617
$Y_1 - Y_2$	120V	1.0V	1.003	1	"		/	$Y_1 - Y_2$	+	
$Z_1 - Z_2$	120V	1.0V	1.000	1	"		/	$Z_1 - Z_2$	+	
		$X_1 - X_2$	SEC WINDING RES = 0.5Ω							
		$Y_1 - Y_2$	" "	"	" = 0.5Ω					
		$Z_1 - Z_2$	" "	"	" = 0.5Ω					

INSULATION: Hi - GRD 100KMΩ + @ 5KVDC
Lo - GRD 10KMΩ + @ 500VDC

REMARKS:

TESTED BY: D. CHIPPENDALE

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Customer: UNITED POWER (BCR)
Manufacture: (W)
Type: OPC 69

C.B., Transformer, or Line Position: SCT L2
C.B., or Transformer Serial No.: LK50618
Job No.: C-

Ratio							Polarity			Serial Number & Position
Supply		Primary / Secondary Lead	Meas. Volts / Amps	Calc. Volts / Amps	Name Plate Ratio	Exc. Amps Res.	Connection		Met. Defl.	
Primary / Secondary	Volts / Amps						Batt	Meter		
$X_1 - X_2$	120V	1:100V	1.002	1	1200/600/5/5/5		H1-H4	X_1-X_2	+	LK50618
$Y_1 - Y_2$	120V	1:0	1.001	1	"		H1-H4	Y_1-Y_2	+	
$Z_1 - Z_2$	120V	1:0	1.002	1	"		H1-H4	Z_1-Z_2	+	

Insulation: Low - Hi & GRD. (500 V_{DC}) = 10K MΩ + (∝ 1 min & 10 min).
Hi - Lo & GRD. 5000 V_{DC} = 100K MΩ + (∝ 1 min & 10 min).

Remarks: Sec Res. $X_1 - Y_2 = 0.5\Omega$
$Y_1 - Y_2 = 0.5\Omega$
$Z_1 - Z_2 = 0.5\Omega$.

Tested By: D. CHIPPENDALE C.E.

Date: OCT. 4/83

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Customer UP-BCR

Manufacture: (W)

Type OPC 69

C.B., Transformer, or Line Position SCT-C1

C.B., or Transformer Serial No.

Job No. C-

Ratio							Polarity			Serial Number & Position
Supply		Primary / Secondary Lead	Meas. Volts Amps	Calc. Volts Amps	Name Plate Ratio	Exc. Amps Res.	Connection		Met. Defl	
Primary / Secondary	Volts Amps						Batt	Meter		
$X_1 - X_2$	120V	1.0V (H1-H4)	1.000	1.0	300/600-5-B3		$H_1 - H_4$	$X_1 - X_2$	+	LK50621
$Y_1 - Y_2$	120V	1.0V	1.007	1.0	"		"	$Y_1 - Y_2$	+	
$Z_1 - Z_2$	120V	1.0V	0.998	1.0	"		"	$Z_1 - Z_2$	+	
		$X_1 - X_2$	SEC	WINDING	RES =	0.5Ω				
		$Y_1 - Y_2$	"	"	" =	0.5Ω				
		$Z_1 - Z_2$	"	"	" =	0.5Ω				

REMARKS: H_1-GRD = 100K MΩ + @ 5KVDC.
X_2 GRD - 10K MΩ + @ 500VDC

- HV. JUMPERS CHANGED TO GIVE 600/5

TESTED BY: D. CHIPPINDALE C&E

DATE: OCT 6/83.

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

C.B., TRANSFORMER, OR LINE POSITION C.1

C.B., OR TRANSFORMER SERIAL NO.

JOB NO. C-

...ER UP-BCR

...UFACTURE (W)

...E 15KV 10L200

SUPPLY PRIMARY	SUPPLY SECONDARY VOLTS	SUPPLY SECONDARY AMPS	RATIO PRIMARY	RATIO SECONDARY LEAD	RATIO MEAS. VOLTS	RATIO MEAS. AMPS	RATIO CALC. VOLTS	RATIO CALC. AMPS	RATIO NAME PLATE RATIO	EXC. AMPS	POLARITY CONNECTION BATT	POLARITY CONNECTION METER	POLARITY MET. DEFL	SERIAL NUMBER & POSITION
X1-X2	100		1.0V	H_1-H_2	1.000		1.0		500/5		H_1-H_2	X_1-X_2 (B-W)	+	830807/2
			(X_1-X_2 SEC WINDING RES = 0.5Ω)						(100-1)					
X1-X2	100		1.0V		1.000		1.0		500/5		H_1-H_2	X_1-X_2 (B-W)	+	830807/1
			(X_1-X_2 SEC WINDING RES = 0.5Ω)											

RELATIONS

REMARKS: H_1-GRD 100 KΩ + @ 5KVDC
L_0-GRD 10KΩ + @ 500VDC.

TESTED BY: D. CHIPPENDALE CLT

DATE: OCT 6/83.

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION VII

230 & 50 KV VOLTAGE TRANSFORMERS

The 230 and 50 KV voltage transformers have been visually inspected, meggered, polarity and ratio tested. Please refer to attached test sheets.

Ratio Tests via Doble testing, please refer to Appendix 'A' for test results.

Power Factor Tests, please refer to Appendix 'A' Doble Tests for test results.

All required oil samples have been taken. Please refer to Appendix 'B' for test results.

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

stomer U.P. BCR

nufacture: (W)

Type PCA9

C.B., Transformer, or Line Position 2VT-B1

C.B., or Transformer Serial No.

Job No. C-

Ratio							Polarity			Serial Number & Position
Supply		Primary Secondary Lead	Meas. Volts Amps	Calc. Volts Amps	Name Plate Ratio	Exc. Amps Res.	Connection		Met. Defl.	
Primary Secondary	Volts Amps						Batt	Meter		
		Style No.	3905B	82A67						
			3CALQ55	93200						
		-	Ratio and Capacitance Tests Via Doble. (BC 14)							
		-	Confirmation of Polarity Via Load Tests.							

ULATION: Hi - Grd. 100 Kmin @ 5000 Vdc.
Lo - Grd. 10 Kmin @ 500 Vdc.

REMARKS:

Tested By: D. Chimendale CET

Date: Oct 6/85

CHIPPENDALE ELECTRICAL SERVICES LTD.

C. T. & P. T. CHECK SHEET

Customer U.P. BCR.
Manufacture: (W) APT
Type

C.B., Transformer, or Line Position SVT-B1
C.B., or Transformer Serial No. LK 50623
Job No. C-

Ratio							Polarity			Serial Number & Position
Supply		Primary Secondary Lead	Meas. Volts Amps	Calc. Volts Amps	Name Plate Ratio	Exc. Amps Res.	Connection		Met. Defl.	
Primary Secondary	Volts Amps						Batt	Meter		
							$H_1 - H_2$	$X_1 - X_2$	+	LK 50623
							"	$X_1 - X_3$	+	
							"	$Y_1 - Y_2$	+	
							"	$Y_1 - Y_3$	+	

RATIO VIA DOBLE. (BCH)

PRIMARY WINDING RES. = 1.39 MΩ.

SEC WINDING RES.

$X_1 - X_3$ = 10.53 mΩ		$Y_1 - Y_3$ =	9.62 mΩ
$X_2 - X_3$ = 6.96		$Y_2 - Y_3$ =	5.99
$X_1 - X_2$ = 5.83		$Y_1 - Y_2$ =	5.18

Regulations:
Remarks: H_1 - GRD 100 KMΩ @ 5KVDC
L_0 - GRD 10 KMΩ @ 500VDC.

Tested By: D. Chippendale Ltd
Date: Oct 6/83.

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Tamer UP - BCR
Manufacture (W)
Type APT.

C.B., Transformer, or Line Position SVT-B2
C.B., or Transformer Serial No. LK 50624
Job No. C-

Ratio							Polarity			Serial Number & Position
Supply		Primary Secondary Lead	Meas. Volts Amps	Calc. Volts Amps	Name Plate Ratio	Exc. Amps Res.	Connection		Met. Defl.	
Primary Secondary	Volts Amps						Batt	Meter		
							H_1-H_2	X_1-X_2	+	LK50624
							"	X_1-X_3	+	
							"	Y_1-Y_2	+	
							"	Y_2-Y_3	+	
		RATIO VIA DOBLE (BCH)								

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Tamer UP. BCR (W)
Manufacture
Type APT

C.B., Transformer, or Line Position SVT-L1
C.B., or Transformer Serial No. LK 50662
Job No. C-

Ratio							Polarity			Serial Number & Position
Supply Primary - Secondary	Volts Amps	Primary Secondary Lead	Meas. Volts Amps	Calc. Volts Amps	Name Plate Ratio	Exc. Amps Res.	Connection Batt	Connection Meter	Met. Defl.	
							H_1-H_2	x_1-x_2	+	LK50662
							"	x_1-x_3	+	
							"	Y_1-Y_2	+	
							"	Y_1-Y_3	+	
		RATIO VIA DOBLE.								
			BCH							
			PRIMARY WINDING RES. =				1.9 KMΩ.			
			SEC. WINDING RES.							
			X_1-X_3 = 10.21 mΩ				Y_1-Y_3 = 11.30 mΩ.			
			X_2-X_3 = 6.84				Y_2-Y_3 = 6.79			
			X_1-X_2 = 5.72				Y_1-Y_2 = 5.98			

Insulation: H_1 - GRD 100KMΩ @ 5KVDC
Remarks: H_2 - GRD 10KMΩ @ 500VDC.

Tested By: D. CHIPPENDALE C.E.

CHIPPENDALE ELECTRICAL SERVICES LTD.

C.T. & P.T. CHECK SHEET

Tomer U.P. - BCR
NUFACTURE (W)
TYPE APT

C.B., TRANSFORMER, OR LINE POSITION SVT-L2
C.B., OR TRANSFORMER SERIAL No. LK 50663
JOB No. C-

RATIO							POLARITY			SERIAL NUMBER & POSITION
SUPPLY: --		PRIMARY SECONDARY LEAD	MEAS. VOLTS AMPS	CALC. VOLTS AMPS	NAME PLATE RATIO	EXC. AMPS RES.	CONNECTION		MET. DEFL	
PRIMARY SECONDARY	VOLTS AMPS						BATT	METER		
							$H_1 - H_2$	$X_1 - X_2$	+	LK50663
							"	$X_1 - X_3$	+	
							"	$Y_1 - Y_2$	+	
							"	$Y_1 - Y_3$	+	
		RATIO VIA (BCH)		DOUBLE.						
			PRIMARY WINDING RES. = 1.38 Kmn.							
			SEC. WINDING RES.							
			$X_1 - X_3$ = 9.72				$Y_1 - Y_3$ = 10.41		mn.	
			$X_2 - X_3$ = 6.32				$Y_2 - Y_3$ = 7.68			
			$X_1 - X_2$ = 5.60				$Y_1 - Y_2$ = 6.73			

INSULATION: H_1-LO 100KMΩ + @ 5KVDC.
LO-GRD 10KMΩ + @ 500VDC.

REMARKS:

TESTED BY: D. CHIPPENDALE

DATE: OCT 4/83.

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION VIII

50 KV RESISTORS

(A) Nameplate Data:

R1 - Serial No. 102577, 1000 ohms, 50A, manufacturer - C. Schiewindt, K.G. Neuenrande.

R2 - Serial No. 102577, 1000 ohms, 50A, manufacturer - C. Schiewindt, K.G. Neuenrande.

(B) Resistance Tests:

R1 - Insulation Resistance @ 5 KV DC = infinity
- Resistance @ 5°C = 969 ohms.

R2 - Insulation Resistance @ 5 KV DC = infinity
- Resistance @ 5°C = 964 ohms

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION IX

CAPACITOR BANK

The capacitor bank was hi-pot tested to 50 KV DC. Please refer to attached test sheet.

Capacitance readings were taken on both banks. The results are as follows:

1) 12MVAR at 72KV or 765A KVA at 57.5 KV
2) Calculated capacitance 6.157 micro farads total to 3.078 micro farads each leg.
3) Measured capacitance 6.588 micro farads total: North 3.284 micro farads; South 3.288 micro farads.
4) % Unbalance 3.288-3.284/3.284 x 100 = 0.12%
5) Fuse Type Westinghouse 5737802G16 - continuity Ok.

DCR/AK/pj

SERVING BRITISH COLUMBIA THE YUKON AND NORTHWEST TERRITORIES

CHIPPENDALE ELECTRICAL SERVICES LTD.

3252 BETA AVENUE, BURNABY, B.C. V5G 4K4 (604) 291-9681

CAPACITOR BANK.

HIPOT TEST

Job # C-

Date OCT 4/83.

Customer UP - BCR SUB

Job location 230KV BCR

Cable type & voltage CAP BANK. "C1"

Weather conditions & temperature 5°C DRY

Comments ALL FUSES CHECKED FOR CONT. -OK.

(BUSING TIED IN TEMP FOR TEST)

Test volts (kv)	Duration (min.)	Microamps leakage. TOTAL BANK TO GRD		
10	1	0		
20	1	0		
30	1	0		
40	1	10		
50	1	15		
50	5	15		
		1 TEST. BOTH BANKS		

Tester D. CHRISTENSEN

OUR ONLY BUSINESS IS SERVICE

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION X

REACTOR

Trench Electric - Harmonic Filter Reactor, Serial No. 11958-1, 80°C Rise, 250A, 50 KV:

Rated Inductance - 142.6 m.h.

Measured Inductance - 138.8 m.h.

Winding Resistance = 0.036 milliohms

Insulation Resistance @ 5KV DC = infinity.

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

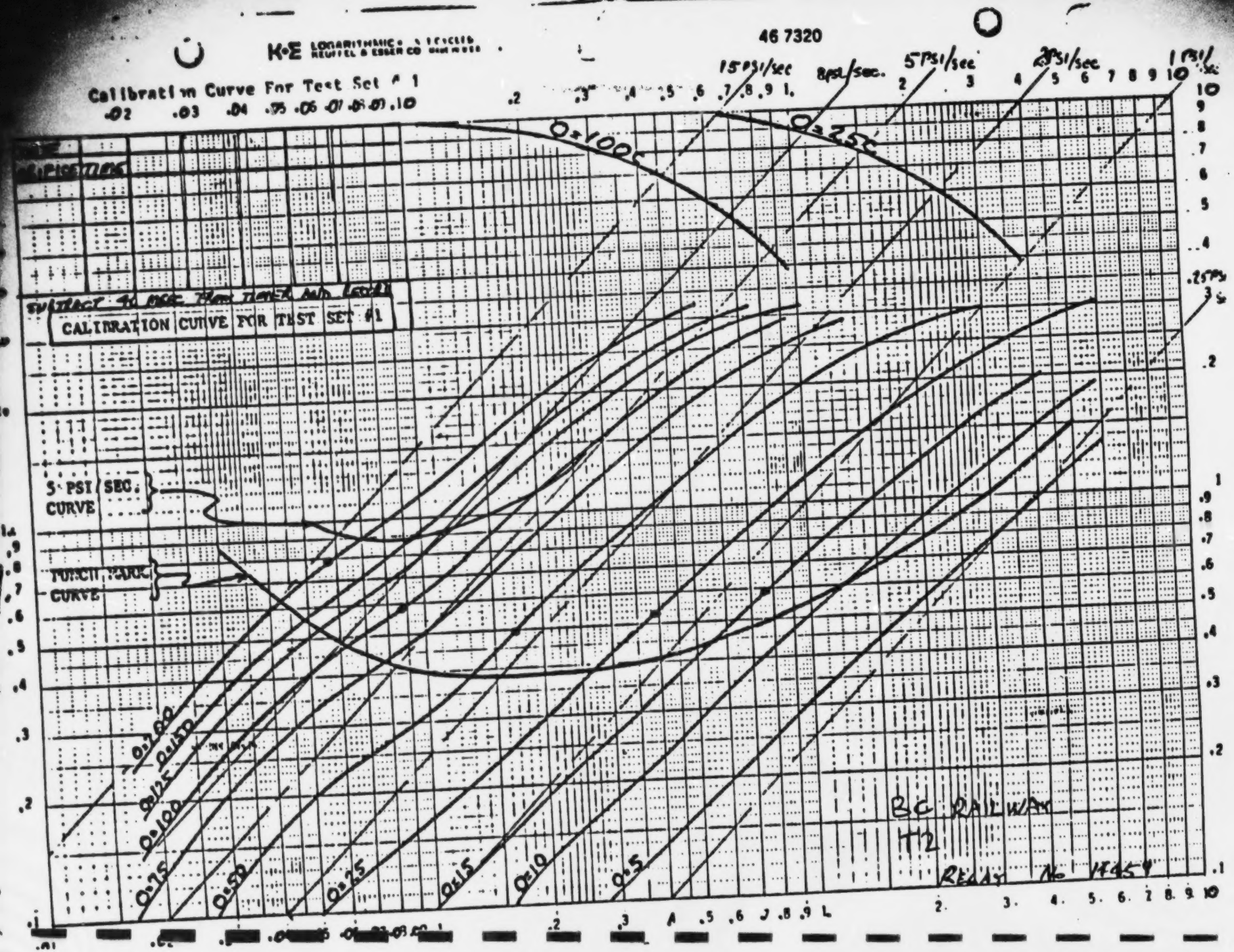
Date: November 22, 1983

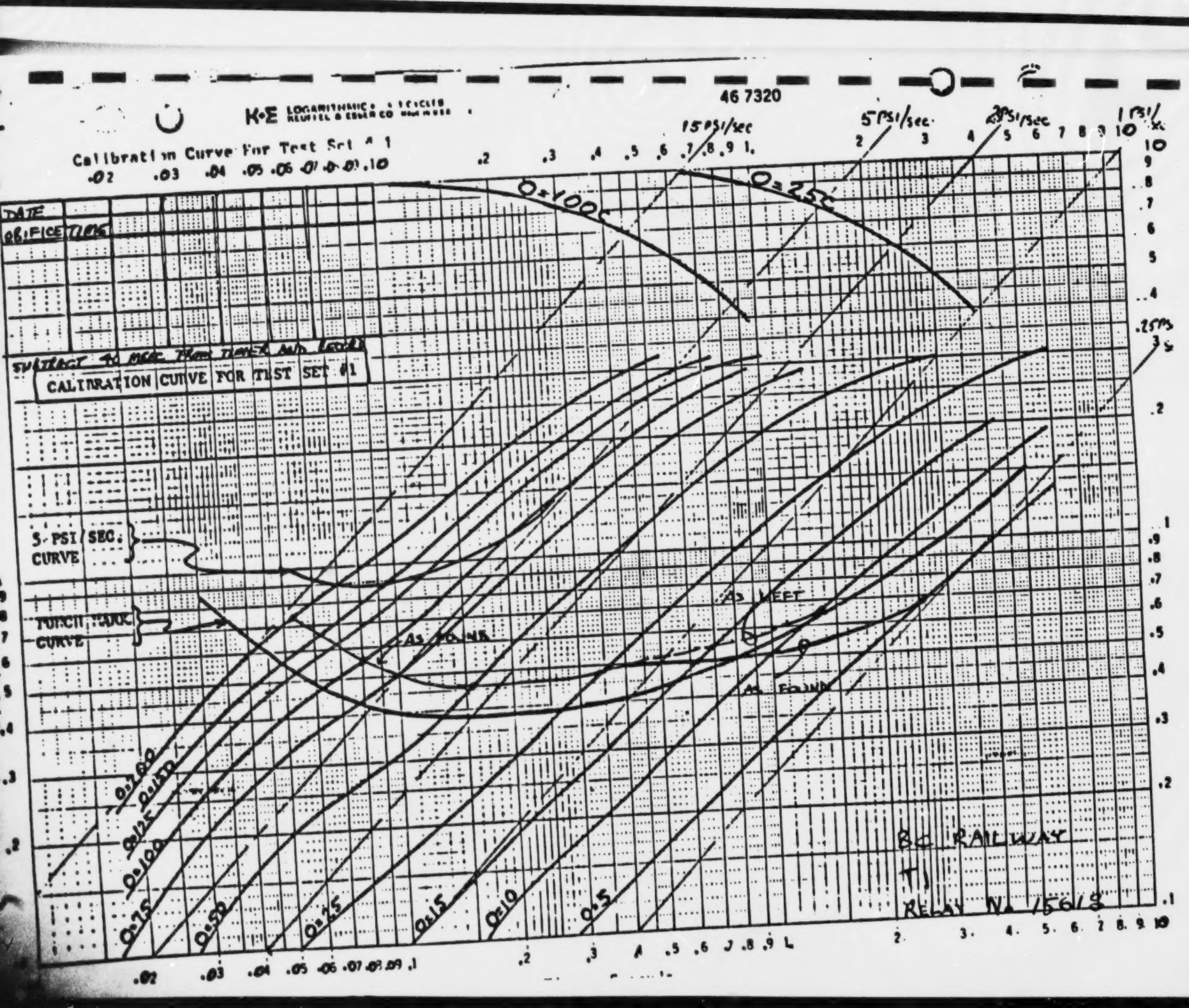
SECTION XI

TRANSFORMER GAS RELAYS

The gas relays have been tested and calibrated using a B.C. Hydro Gas Relay Test set. These tests were witnessed by Mr. Jack Dool, Canadian General Electric. Please refer to the attached test sheets for T1 and T2.

DRC/pj


K&E LOGARITHMIC 3 CYCLES
46 7320
Calibration Curve For Test Set # 1
.02 .03 .04 .05 .06 .07 .08 .09 .10
.2 .3 .4 .5 .6 .7 .8 .9 1.
15 PSI/sec
8 PSI/sec.
5 PSI/sec
2 PSI/sec
1 PSI/
2 3 4 5 6 7 8 9 10
10 9 8 7 6 5 4 .25 PSI 3 2 1 .9 .8 .7 .6 .5 .4 .3 .2 .1
Q=100
Q=25
CALIBRATION CURVE FOR TEST SET #1
5 PSI/SEC. CURVE
TORCH PURGE CURVE
Q=200
Q=125
Q=100
Q=75
Q=50
Q=25
Q=15
Q=10
Q=5
BC RAILWAY
HT2
READY
No 1745
.01 .02 .03 .04 .05 .06 .07 .08 .09 .1 .2 .3 .4 .5 .6 .7 .8 .9 1. 2. 3. 4. 5. 6. 7. 8. 9. 10.


46 7320
K·E LOGARITHMIC & TRIGLOB
Calibration Curve For Test Set # 1
.02 .03 .04 .05 .06 .07 .08 .09 .10
.2 .3 .4 .5 .6 .7 .8 .9 1.
15 PSI/sec
5 PSI/sec
2 PSI/sec
1 PSI/sec
2 3 4 5 6 7 8 9 10
Q=100
Q=25
DATE
OFFICE TIME
SUBTRACT 30 MIN. FROM TIMES AND TESTS
CALIBRATION CURVE FOR TEST SET #1
5 PSI/SEC. CURVE
TORCH CURVE
AS FOUND
AS LEFT
AS FOUND
Q=200
Q=150
Q=100
Q=75
Q=50
Q=25
Q=15
Q=10
Q=5
B.C. RAILWAY
TYPE
RELAY No. 1561S
.02 .03 .04 .05 .06 .07 .08 .09 .1
.2 .3 .4 .5 .6 .7 .8 .9 1.
2. 3. 4. 5. 6. 7 8. 9 10

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: ... United Power Limited .....

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION XII

BATTERY CHARGER

Adjusted VR1 Rheostat on PCB-1 cards to give the following ranges:

	Left Charger #1	Right Charger #2
Float Range	124-134	124-134
Equalize Range	134-144	134-144
Set Float at:	127	127
Set Equalize at:	138	138
A.C. Failure check	Ok	Ok
D.C. Low Voltage Alarm	115V DC	115V DC
D.C. High voltage Alarm	P.U. at 145V but no tripping	145V DC C8 trips Ok
D.C. Ground (+ or - to Grd.)	∠25K ohms	∠25K ohms
A.C. Ripple (from no load to 50A load)	less than .5V	less than .5V
Current limit Status at:	53A	53A

NOTE : D.C. High voltage Alarm card on Charger #1 is defective. Recommend replacement.

A.Kay/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

BATTERIES

#	Temperature °F	Specific Gravity
1	60	1.220
2	60	1.215
3	61	1.220
4	62	1.213
5	62	1.213
6	62	1.215
7	62	1.215
8	62	1.215
9	62	1.215
10	62	1.215
11	62	1.215
12	62	1.220
13	62	1.215
14	62	1.215
15	62	1.220
16	62	1.220
17	62	1.220
18	62	1.215
19	62	1.210
20	62	1.210
21	63	1.215
22	63	1.220
23	63	1.220
24	63	1.210
25	63	1.215
26	63	1.220
27	63	1.220
28	63	1.220
29	63	1.215
30	63	1.215
31	63	1.210
32	63	1.215
33	63	1.210
34	63	1.215
35	63	1.215
36	63	1.215
37	63	1.210
38	63	1.220
39	64	1.215
40	64	1.210
41	64	1.215
42	64	1.215
43	64	1.215
44	64	1.210
45	65	1.220
46	65	1.215
47	65	1.215
48	65	1.215
49	65	1.215
50	65	1.200
51	65	1.210
52	65	1.215
53	64	1.220
54	64	1.215
55	63	1.210
56	63	1.215
57	62	1.210
58	62	1.215

A.Kay/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

SECTION XIII

GROUND GRID CONNECTIONS

Tested all ground grid connections including leads brought out for T1 transformer. Applied approximately 100 amps at .2 volts.

Also 8 ground connections along the fence were tested.

The following connections were found not connected to the ground grid:

(a) Two connections for 230KV, T2 bus supports

(b) 5MOD-B23 supports

All three connections were connected and retested.

A.Kay/pj

SECTION XIV

PROTECTION & CONTROL

(A) 230 KV Bus:

C.T.s

Test C.T. wiring from C.T. secondary terminals by current injection:
: AX1 & BX1 through 50/51 HV and 50/51 N relays.
- CX C.T. shorted at the panel.

: AY1 - AY2 C.T. to the 2CT-1M current test block.
- BY & CY C.T.s shorted at the panel.

Both sets of C.T.s and their cables were meggered (2000 meg ohms).

2VT-B1

All cabling was tested from P.T. secondary terminal blocks to panel test blocks, 2VT-B1-230M & 2VT-B1-R/B1.

2DS-321

Tested correct operation of indicating lights (R&G) and tested correct contacts wired to SCADA.

Note : The indicating lights were not connected on the Glenayre panel.

2CB-L321

Tested operation of the breaker, proving local and remote operations, correct indication, trip-coil supervision, and trip tested breaker from:
50/51N-HV, 94-T2, 94-T1,
50/51 HV (A&BØ) 86-T2, 86-T1, proving all trip switches.

Note : 86-T1 relay was not on site at time of testing. Tripping tested by touching wires DPP & DPW.

Tested for correct indication to SCADA.

Proved that 86-T1 and 68-T2 relays block C.B. closing.

Note : 86-T1 relay was not installed at time of testing. Wires DQS and DQT are bolted at the place where the relay is to be installed.

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

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"b"

Meggered D.C. System : primary D.C. - 1000 meg ohms
secondary D.C. - 500 meg ohms.

(B) T1 Protection:

Refer drawings 04-10 Sheet 1, and 04-13 sheets 1, 2 & 3.

Primary

Proved 86-T1 relay resetting circuit from SCADA via 2MOD-T1 "b" contacts.

Proved 5CB-T1 tripping from 86 Bus relay.

Provide operation of 98-5CB-T1 trip coil supervision relay via 5CB-T1 "a" and "b" contacts.

Note : (1) Coil "A" supervision light has a lamp socket of the wrong type.
(2) 86-T1 L.O. relay is missing.

Standby

Proved 5CB-T1 tripping from 94-T1, 2-50F-C1, 2050BF-L2, 20-50 BF-L1.

Proved breaker tripping from local control switch and SCADA contacts.

Proved operation of 98-5CB-T1-B relay, trip coil supervision, via 5CB-T1 "a' amd "b" contacts.

Proved breaker closing by local control switch and SCADA contacts via 86-T1, 86-B relays and 2MOD-71, 5MOD-B12, 5MOD-B23, and 5MOD-T1 auxiliary switches.

Note : 86-T1 "b" contact (wires DNR-DNS) were proved and bolted together until installation of the relay.

Proved operation of 2MOD-T1 from local control switch and SCADA via 5CB-T1 breaker "b" contact.

Proved operation of 5MOD-T1 from local control switch and SCADA via 5CB-T1 breaker "b" contacts.

C.T.s

C.T. cables from T1 to Panel were not proved as T1 was not installed.

5CB-T1 : tested C.T. cables by injecting current at C.T. terminals and measuring at test blocks as follows:

5CT-T1 - X1-X2 at 29-T1LV test block and 51-T1LV and 67-T1LV relays.

Note : Wrong type test block is installed.

Y1-Y2 shorted and grounded at C.T.

Z1-Z2 via 5CT-1-87T1 to 87-T1 relay.

All current and control wiring meggered; insulation better than 500 meg ohms.

(C) T2 Protection:

Primary

Tested operation of 63X-T2 from 63-T and 63-PRV relays by jumpering terminals at the transformer.

Operated 49-3X-T2 relay similarly from 49W-T and 26T terminals.

Tested operation of 86-T2 L.O. relay and its resent from SCADA, proving that reset can be made only when 2MOD-T2 and 5MOD-T2 are open.

Tested tripping of 5CB-T2 from 86-T2 and 86-Bus relays.

Proved operation of the trip-coil supervision relay 98-5CB-T2-A relay via 52 "a" and 52 "b" contacts.

Refer to drawing 04-15, sheet 1.

Standby

Tested operation of 94-T2 relay and tripped 5CB-T2 breaker from: 67T2-LV, 51-T2LV, 94T2, 2-50BF-C1, 2-50BF-L2, and 2-50BF-L1.

Proved operation of 98-CB-T2-B relay via 52 "a" and 52 "b" contacts.

Tested breaker tripping from local control switch and from SCADA.

Tested breaker closing from local control switch and from SCADA, proving close blocking from 86T2, 68B, 2MOD-T2, 5MOD-T2, 5MOD-12 and 5MOD-23.

Refer to drawing 04-15, sheets 2 and 3.

2MOD-T2

Tested MOD operation from local control switch and SCADA, proving it can be operated only when 5CB-T2 is open.

5MOD-T2

Tested MOD operation from local control switch and SCADA, proving that it can be operation only when 5-CB-T2 is open.

C.T.s

Tested current transformer wiring by injection currents at C.T. secondary terminals and measuring at test blocks as follows:

2CT-3 (200-5) : AX1-AX2 and BX1-BX2 via 2CT3-87T2 block to 87T2 relay.
: Checked accuracy of auxiliary C.T. ratio
: CX1-CX2 and DX1-DX2 via 2CT-3R block and 50/51 A, B, and N relays.
: EX1-EX2 via 2CT-3M block and metering circuit.
: FX1-FX2 C.T. is shorted and grounded.

5CT-2 : GX1-GX2 via 5CT-87B-1 block to 87B relay.
: HX1-HX2 via 5CT-2-87T block to 87T2 relay.

Refer to drawing 04-10, sheets 1 and 2.

5CB-T2

5CT-T2(600-5) : X1-X2 via 29-T2-LV to 51-T2-LV and 67-T2-LV relays.
Note : wrong type test block is used.
: Y1-Y2 shorted and grounded at C.T.
: Z1-Z2 via 5CT-2-87-T2 to 87-T2 relay.

All current and control wiring and cables were meggered; insulation is better than 500 meg ohms.

(D) 5-L1 Protection:

Refer to drawing 04-16, sheet 1.

Primary

Proved operation of 94L1, 50/51X-L1 relays.

Tested operation of 59L1 relay to the annunciation panel (50KV bus fault).

Tested 5CB-L1 tripping from 94-L1, 86-Bus, and 50/51X relays.

Tripping for 81X was done by B.C. Hydro.

Proved operation of 98.5CB-L1-A relay via 52 "a" and 52 "b" contacts.

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"e"

Standby

Refer to drawing 04-16, sheet 2.

Tested breaker tripping from local oontrol switch and SCADA.

Automatic Reclosing

Tested three conditions of auto-reclosing:

(1) Breaker tripped by 94L1 relay with no potential after reclosing. Breaker trips following by 5MOD-2-L1 opening with subsequent second breaker trip-out and 5MOD2-L1 closing, i.e. the line remains de-energized.

(2) Potential is restored after circuit breaker reclosing. 5MOD2-L1 closes after the time delay.

(3) Potential is restored after circuit breaker reclosing, but 5MOD2-L1 failed to reclose. 5CB-L1 trips out again.

Refer to drawing 04-16, sheet 3.

Proved 5CB-L1 closing by local control switch and SCADA, proving close blocking by 86-Bus, 5MOD1-L1, 5MOD2-L1, 5MOD3-L1.

5MOD1-L1

Tested operation of MOD by local control switch and SCADA only when 5CB-L1 is open.

5MOD2-L1

Rewired 79L1-A and 52 "b" contacts in the MOD control so that the MOD can be operated by control push buttons at MOD when the 5CB-L1 breaker is open.

5MOD3-L1

Proved operation of MOD by local control switch and SCADA when 5CB-L1 is open.

C.T.s

Tested current transformer wiring by injection of 2 amps at C.T. terminals as follows:

5CT-L1 (600-5) : X1-X2 via 5CT-3R test block to 50BF-L1, 50/51 L1 and 21L1
: Y1-Y2 via 5CT-3M test block to metering
: Z1-Z2 via 5CT-87-B2 test block to 87B relay

5VT-L1 : via 5VT-L1-R21/59 test block to 27AR relay by application of 115 volts at P.T. fuse blocks.

All C.T., P.T., and control wiring and cabling were meggered; insulation is better than 500 meg ohms.

All solid state devices were not meggered.

(E) 5-L2 Protection:

Refer to drawing 04-17, sheets, 1, 2, and 3 and to drawing 04-10, sheet 2.

Primary

Proved operation of 94-L2, 50/51X-L2 relays.

Tested operation of 59-L2 relay to the annunciation panel (50KV Bus fault).

Tested 5CB-L2 tripping from 94-L2, 86-Bus, and 50/51X relays.

Tripping from 81X relay was done by B.C. Hydro.

Proved operation of 98-5CBDL2A relay via 52 "a" and 52 "b" contacts.

Standby

Tested breaker tripping from local control switch and SCADA.

Automatic Reclosing

Tested three conditions of automatice reclosing as follows:

(1) Breaker tripped by 94-L2 relay with no potential after reclosing. Breaker trips followed by 5MOD2-L2 opening with subsequent second breaker trip out and 5MOD2-L2 closing, i.e. the line remains de-energized.

(2) Potential is restored after circuit breaker reclosing. 5MOD2-L2 closes after a time delay.

(3) Potential is restored after circuit breaker reclosing, but 5MOD2-L2 failed to reclose. 5CB-L2 trips again.

Proved 5CB-L2 closing by local control switch and SCADA, proving close blocking by 86-Bus, 5MOD1-L2, 5MOD2-L2, and 5MOD3-L2.

5MOD1-L2

Tested operation of MOD by local control switch and SCADA only when 5CB-L2 is open.

5MOD2-L2

Rewired 79-L2-A and 52 "b" contacts in the Mod control circuit so that the MOD can be operated by control push buttons at MOD when 5CB-L2 is open.

5MOD3-L2

Proved operation of MOD by local control switch and SCADA when 5CB-L2 is open.

C.T.s

Tested current transformer wiring by injection of 2 amps at C.T. terminals as follows:

5CT-L2 (600-5) : X1-X2 via 5CT-5R test block to 50BF-L2, 50/51-L2 and 21-L2 relays.
: YL-Y2 via 5CT-5M test block to metering.
: Z1-Z2 via 5CT-87B/3 test block to 87B relay.

5VT-L2 : via 5VT-L2-R21/59 test block to 27AR-L2 relay by application of 115 volts at P.T. fuse blocks.

All C.T., P.T., and control wiring and cabling were meggered; insulation is better than 500 meg ohms.

All solid state devices were not meggered.

(F) Capacitor Protection:

Refer to drawing 04-14, sheets 1 & 2, and drawing 04-10, sheet 2.

Tested current transformer wiring and cabling by current injection as follows:

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"h"

5CT-C1 : X1-X2 C.T. terminals via 5CT-4R test block to 50/51 CT and 50BF-C1 relays
: Y1-Y2 C.T. terminals via 5CT-4M test block to metering circuits
: Z1-Z2 C.T. terminals via 5CT-87B-2 test block to 87B relay.

100/5 C.T.s : Tested C.T. wiring from 51-X1-X2 C.T. terminals and from 52-X1-X2 terminals via 50A/T test block to 60A/T relay.

In addition, tested the system operation by injecting 3.5 amps primary current into each leg of the capacitor bank and observing operation of 60A relay.

Then by injecting 3.5 amps current into both legs in series, and observing operation of the 60T relay.

Primary

Tested 5CB-C1 tripping from 86 Bus, and 2-60T relays via respective trip switches.

Proved breaker "a" and "b" contacts in the primary coil supervision circuit (98-5CB-C1-A relay).

Standby

Tested operation of 86-C1 relay from 50/51C relay and its reset circuit from SCADA via 5MOD-C1 "b" contacts.

Tested breaker tripping from 86-C1, 50BF-C1 relays.

Proved operation of standby trip-coil supervision relay 98-5CB-C1-B via 5CB-C1 "a" and "b" contacts.

Tested breaker operation and local indication from local control and from SCADA, proving close blocking by 86Bus and 86C1 relays and 5MOD-C1.

5MOD-C1

Proved operation and local indication of MOD from local control switch and SCADA, proving blocking by 5CB-C1 "b" contacts.

All C.T. cables and control wiring was meggered; insulation is above 500 meg ohms.

(G) 50 KV Bus Protection:

Refer to drawing 04-10, sheets 1 & 2, and drawing 04-19 and 04-18.

As mentioned under individual protection, current was injected into 87B relay from 50 KV C.T.s in T1 and T2 (GX1-GX2) and from 5CT-C1, 5CT-L1, and 5CT-L2(Z1-Z2).

Note : Since T1 is not on site, current for T1 was injected in the panel test block only.

It was observed that T1 and T2 currents were 180^{o} out of phase from C1, L1, and L2 C.T.s in the 87B relay.

Operation of 86B relay was tested, including its reset from SCADA.

Battery low voltage (80) agastat relay was not on site at the time of testing and therefore was not tested.

5MOD-12 and 5MOD-23

Operation of both MOD's was tested from local control and SCADA proving blocking of MOD operation by 5CB-T1 and 5CB-T2 breaker "b" contacts.

(H) Comments & Recommendations:

1) Circuit breakers - (a) interlocking switches are not shown on protection and control schematics.
(b) SF6 gas pressure alarm and operation blocking is not shown on protection and control schematics

Recommend to produce breaker schematic made "Canadian" style and included in drawings for operating personnel.

2) Battery Charger - The instruction manual appears to be of a general nature, and does not apply to these particular battery chargers.

3) L2 Distance Relay - appears defective. Repaired and retested.

4) We recommend annual relay inspection, calibration and operational tests of all high voltage components, including operational tests of the automatic reclosing scheme.

These annual tests ensure reliable operation and also provide excellent training for operating personnel under different conditions.

A Kay/pj

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"a"

SECTION XV

ENERGIZATION

(A) 230 KV Potentials:

	A	B	N
2VT-B1-230M : Term. 1, 3, 5 to Grd.	70/0°	70/117°	-
: Term. 18, 20		70/117°	-
: Term. 15, 17	70/0°	70/117°	-
#81 Under Frequency Relay	121/329°		
Currents in 50/51 HV Relays	.56/237°	.56/55°	
Currents in 2CT-1M	.56/237°		

.56A Secondary = .56 x 300/5 = 33.6 amps on 230 KV.

(B) 50 KV Potentials:

5VT-L1 B1/B2M : Term. 5 - 9	107/323°
: Terms. 13 17	108/328°
Relays : 21L1, Terms. 7 - 8	107/328°
: 59L1, Terms. 9 - 10	107/329°
: 67T1, Terms. 7 - 8	107/148°
: 21L2, Terms. 7 - 8	107/329°
: 59L1, Terms. 9 - 10	107/329°
: 67T1, Terms. 7 - 8	107/147°
: 27AR-L2, Terms 9 - 10	107/329°

27AR-L1 relay voltages not measured as L1 was not energized due to defective 5CB-L1.

Note : During energization tests, it was realized that 5VT-B1 and 5VT-B2 were incorrectly connected on the primary side. Corresponding connection was made on the secondary side of both P.T.s.

5VT-L1-B1/B2M Test Block : Terms, 5 - 9 $107/323^{0}$

(C) T2 Protection:

The transformer was loaded with 7.5 MVA capacitor.

Relay 87-T2	: Term. 11	$1.29/86^{0}$
	: Term. 14	$1.27/265^{0}$
	: Term. 15	$1.27/86^{0}$
	: Term. 16	0
	: Term. 12	0
	: Term. 18	$1.29/267^{0}$
50/51-T2 Relay	: AØ	$.82/266^{0}$
	: BØ	$.82/85^{0}$
	: N	0

Check : 1) .82 amps x 200/5 = 32.8 amps, compared with 33.6 amps read in 230 KV overcurrent relays.

2) current in terminal 14 of 87-T2 relay should be equal to .82 x 5.0/3.2 = 1.28 compared with 1.27 measured.

3) Phase angle currents in terminals 14 and 11 are 180^{0} apart, and current in terminal 12 is 0.

4) 50 KV current in relays was measured at 1.29 amps secondary = 1.29 x 600/5 = 154.8 amps. This equals 154.8 x $50/\angle 30$ = 33.6 amps on 230 KV.

This proves correctness of 87-T2 relay connections.

2CT-3M test block, Term. #9	$.82/266^{0}$
51-T2-LV Relay, Term. #g	$1.29/267^{0}$
67-T2-LV Relay, Term. #g	$1.29/267^{0}$

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"C"

(D) Bus Differential:

5CT-87B1	:	Term. #5	$1.29/267^{o}$
	:	Term. #18	$1.29/86^{o}$
5CT-87B2	:	Term. #10	$1.29/267^{o}$
	:	Term. #14	$1.29/86^{o}$

87B Relay Current - 0 amps.

(E) Capacitor Bank:

60A/60T Relay	:	Term. #g	$.77/86^{o}$
	:	Term #5	$.78/267^{o}$

Check : 1) .77 amps secondary = .77 x 100 = 77 amps primary.
Total capacitor current equal 77 x 2 = 154 amps
which is equal to currents measured in T2 protection.

Note : All phase angle measurements were taken with reference to A-Grd. potential with all angles showing the angle by which a vector lags the reference potential.

A.Kay/pj

SECTION XVI

SCADA SYSTEM

The following input contacts were tested to panel terminals (refer to drawing 04-20g, sheet 1 and 2).

T2 : low oil level (71-TA)
: high oil temperature (26T-A)
: gas accumulation (63-A)
: high winding temperature (49W-A).

5CB-T1 : low oil pressure
" -T2 : " " "
" -C1 : " " "
" -L1 : " " "
" -L2 : " " "

5CB-T1 : DC Trip Coil
" -T2 : " " "
" -C1 : " " "
" -L1 : " " "
" -L2 : " " "

Failure Charger #1 - K1-2 and K2-2
Failure Charger #2 - K1-2 and K2-2

A.C. Failure 27 - happens that SCADA is made for normally open contact, while 27 relay has normally close contact.

Shunt Capacitor current Unbalance Alarm - 60A relay.

T1 & T2 Cooling Failure Alarm.

2CB-L321 Trip Coil.

Chargers No. 1 & No. 2, Ground Fault - K6-2
Chargers No. 1 & No. 2, Overvoltage - K3-3

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"b"

2D-321 Status	2DS-L321	"a" & "b" contacts
2CB-321 Status	"a" contact	
5CB-T1 Status	"a" contact	
" -T2 "	"a" contact	
" -C1 "	"a" contact	
" -L1 "	"a" contact	
" -L2 "	"a" contact	
2MOD-T1 Status	"a" and "b" contacts	
2MOD-T2 "	"a" and "b" contacts	
5MOD-T1 Status	"a" and "b" contacts	
" -T2 "	"a" and "b" contacts	
" -B12 "	"a" and "b" contacts	
" -B23 "	"a" and "b" contacts	
" -C1 "	"a" and "b" contacts	
5MOD-1-L1 Status	"a" and "b" contacts	
5MOD-1-L2 Status	"a" and "b" contacts	
5MOD-3-L1 Status	"a" and "b" contacts	
5MOD-3-L2 Status	"a" and "b" contacts	

Note : Contacts from various protective relays on the panel were not tested on assumption that these were tested by Glenayre as part of their panel testing.

A.Kay/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

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"a"

SECTION XVII

GROUND MAT RESISTANCE TESTS

Please find attached test and data sheets for tests(Fall-of-Potential Method) performed on September 17th and October 28th, 1983.

(A) September 17, 1983:

This test was performed before any connections (overhead ground, etc.) were made up. At the time of test, the soil conditions were quite dry. No meter interferance from the B.C. Hydro site was present during the test.

Note: Some of the grounding was not buried at the time of test.

(B) October 28, 1983:

All grounding was complete at the time of test. The tests were witnessed by B. C. Rail.

1) Test No. 1 (0^{o} - 800 feet east of substation). All intentional grounding to B.C. Hydro Sub was disconnected for test purposes. Test results are attached. Test mat resistance equals 1.0 ohms.

   Note : The underground connection boxes to the B.C. Hydro Sub were full of water, therefore, both leads when disconnected were still partially making contact in water.

   Circulating currents from the B.C. Hydro Sub were present during our tests even though we were disconnected. Test No. 1 readings were varying slightly during the test, but did not appear to significantly affect the end results.

2) Test No. 2 (90^{o} - 800 feet east of substation). In this test the test mat remained at the same location as in Test No. 1. In this test, circulating currents were playing havoc with the test instruments. The following results were recorded at the time of test:

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"b"

Distance Out from Sub	Meter Reading
5	0.11*
80	0.95
200	1.70
300	1.52
400	1.00*
500	1.00*

(*) agree with Test No. 1 Results.

3) Test No. 3 (90^{o} - 800 feet east of substation). This test was performed with the grounds tied to the B.C. Hydro Sub. The same mat location was used as Tests No. 1 and No. 2. Circulating currents would not allow the meter to null, ie. below.

Distance Out from Sub	Meter Reading
500	1.0, 1.5 and 2.0

Note : Meter would not null.

4) Test No. 4 (0^{o} - 800 feet east of substation). This test was performed with the grounds tied to the B.C. Hydro Sub. The same mat location was used as Tests Nos. 1, 2, and 3. Circulating currents would not allow the meter to null. Results are as follows:

Distance Out from Sub	Meter Reading
300	0.75 to 0.85
400	0.90 to 1.03
500	1.20

(C) Recommendations:

The isolated B.C. Rail Substation results should be rechecked during the Summer to obtain better isolation from the B.C. Hydro Sub and avoid meter interferance from circulating ground currents.

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LIMITED
3252 Beta Avenue, Burnaby, B.C. V5G 4K4 (604) 291-9681

GROUND MAT RESISTANCE TEST
(Fall - of - Potential Test)

DATE: Sept. 17/83

Test For: United Power

Job No: C- Customer P.O. No:

Job Site Location: BCR Sub. - Tumbler Ridge

Test Data:

1. Outside Temperature: 10°C.
2. Soil Type and Condition: Clay & Gravel
3. Ground Mat Type: Lattice Rod
4. Instrument Used: Gilham II
5. Location of Test Mat: 800ft East
6. Distribution Neutral: Not

Test Results:

1. Test Mat Resistance: 165Ω
2. Traverse Distance ~~(Meters)~~

Traverse Distance	Meter Reading (ohms)
100 ft	1.02
200	1.42
300	1.43
400	1.43
500	1.45
600	2.57
700	6.30
800	165

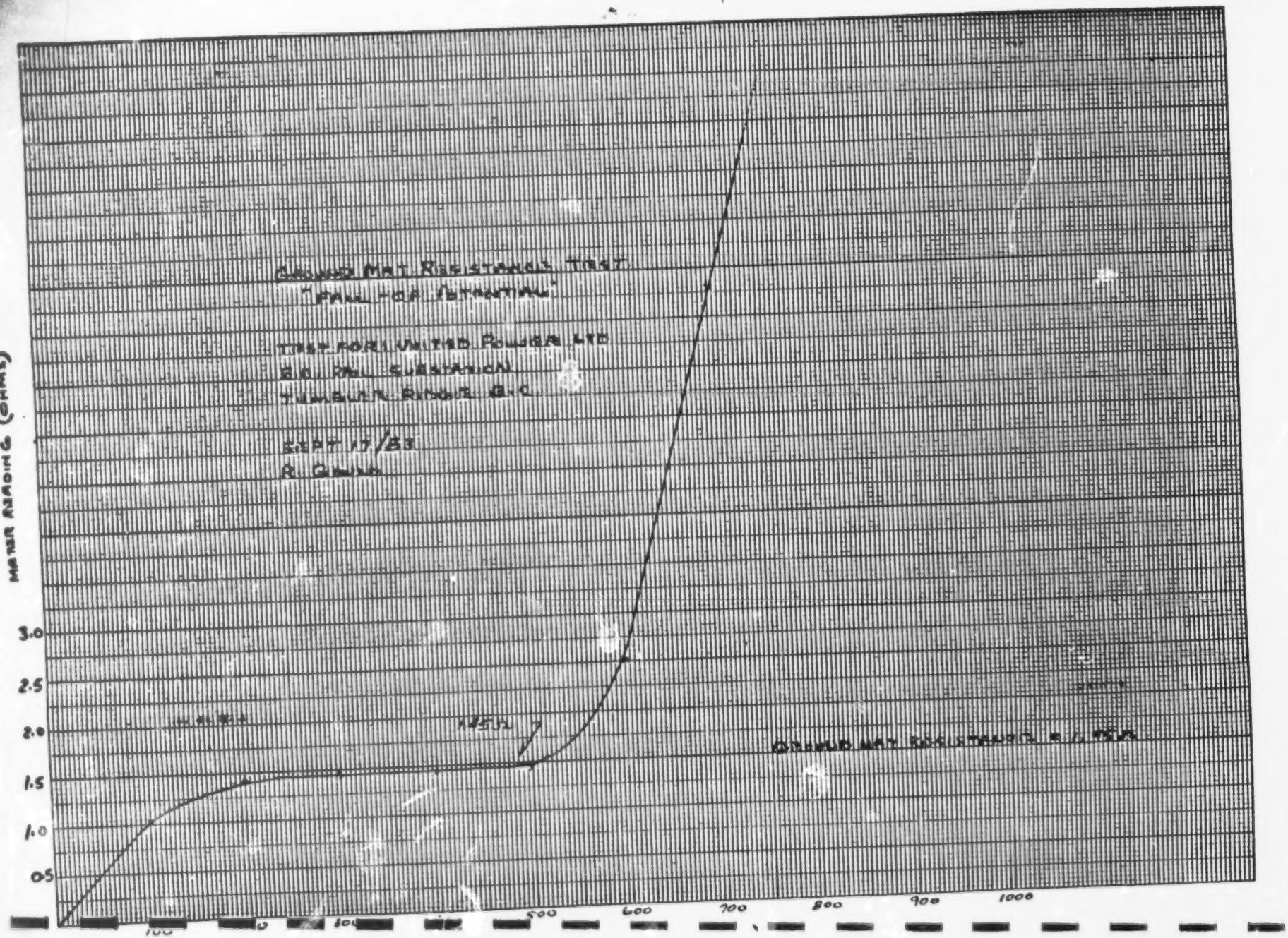
3. Ground Mat Resistance (see attached Fall of Potential Curve) 1.45Ω

Comments: Ground Mat Isolated from B.C.H. - Ground Dry

TESTER: RG

NO. 341-H DIETZGEN GRAPH PAPER
MILLIMETER

DIETZGEN CORPORATION
MADE IN U.S.A.



CHIPPENDALE ELECTRICAL SERVICES LIMITED
3252 Beta Avenue, Burnaby, B.C. V5G 4K4 (604) 291-9681

GROUND MAT RESISTANCE TEST
(Fall - of - Potential Test)

DATE: Oct 28/83

Test For: United Power Ltd.
B.C. Rail Substation
Tumbler Ridge, B.C.

Job No: C- Customer P.O. No:

Job Site Location:

Test Data:

1. Outside Temperature: 5°C.
2. Soil Type and Condition: Moist CLAY & GRAVEL.
3. Ground Mat Type: Refer to dwgs.
4. Instrument Used: Gossen Geohm II
5. Location of Test Mat: 800 ft East
6. Distribution Neutral: Not Connected

Test Results:

1. Test Mat Resistance: 143Ω
2. Traverse Distance ~~[Meters]~~

Traverse Distance	Meter Reading (ohms)
60 ft.	0.49
200	0.96
300	0.96
400	1.02
500	1.2
600	1.32
700	1.87
750	2.8
800	143 (Test Mat)

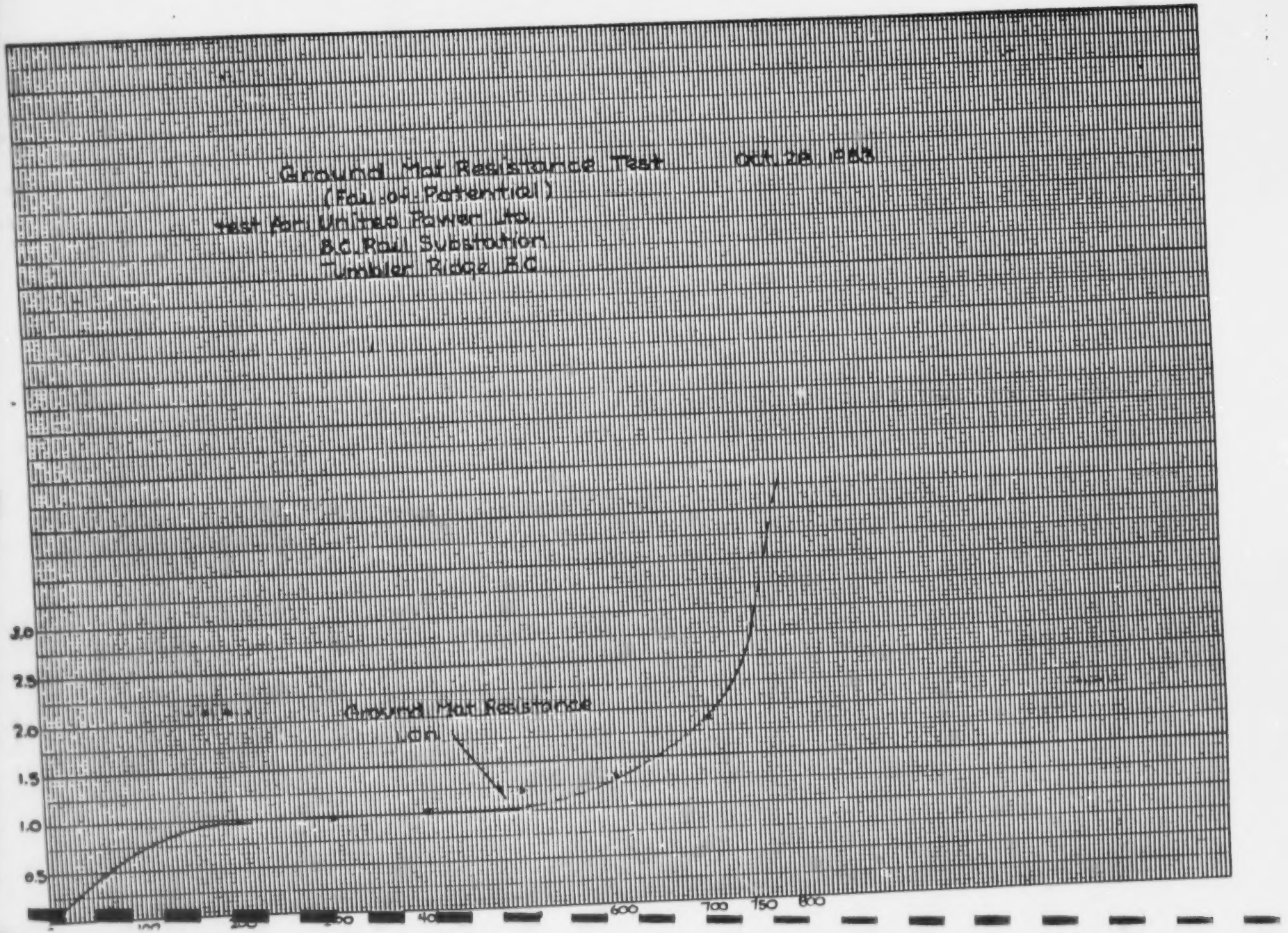
3. Ground Mat Resistance [see attached Fall of Potential Curve] 1.0Ω.

Comments: GROUND MAT ISOLATED FROM B.C. HYDRO

TESTER: D. Chippendale CET

NO. 341-M DIETZGEN GRAPH PAPER
MILLIMETER

DIETZGEN CORPORATION
MADE IN U.S.A.



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SECTION XVIII

OIL LEVELS & GENERAL EQUIPMENT INSPECTIONS

All oil levels have been checked (after samples taken) and appear normal.

Temperature was approximately 2 - 5° when all tests were performed.

All equipment has been checked and inspected externally and appears in good condition.

DRC/pj

CHIPPENDALE ELECTRICAL SERVICES LTD.

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SECTION XIX

GENERAL

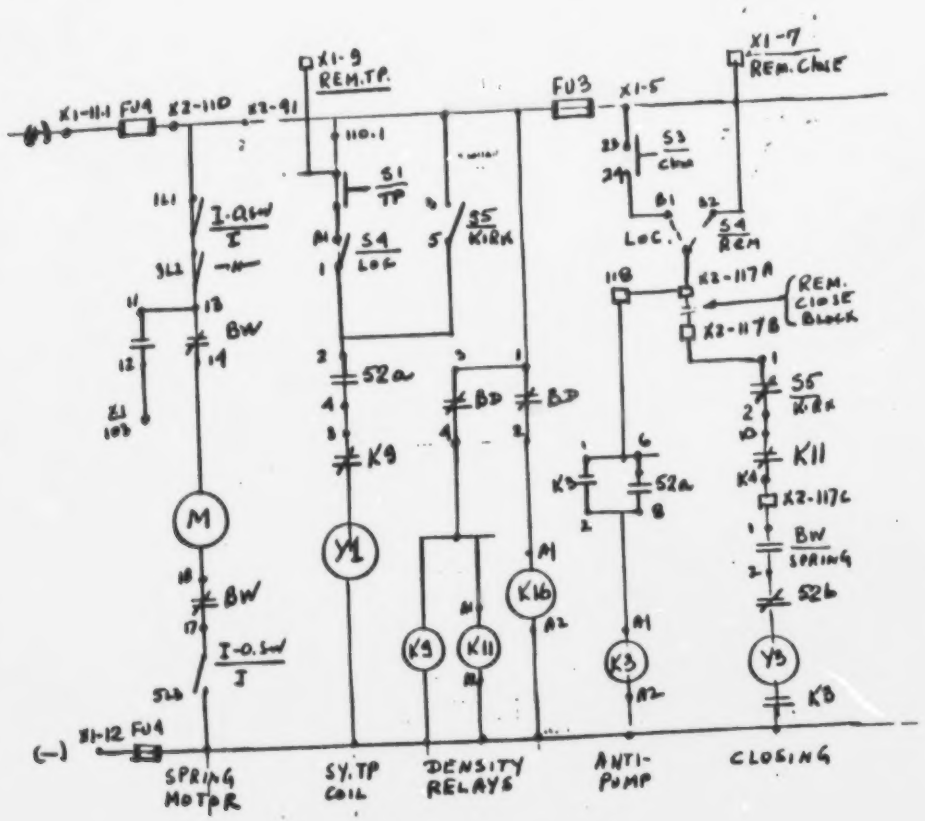
(A) Deficiencies:

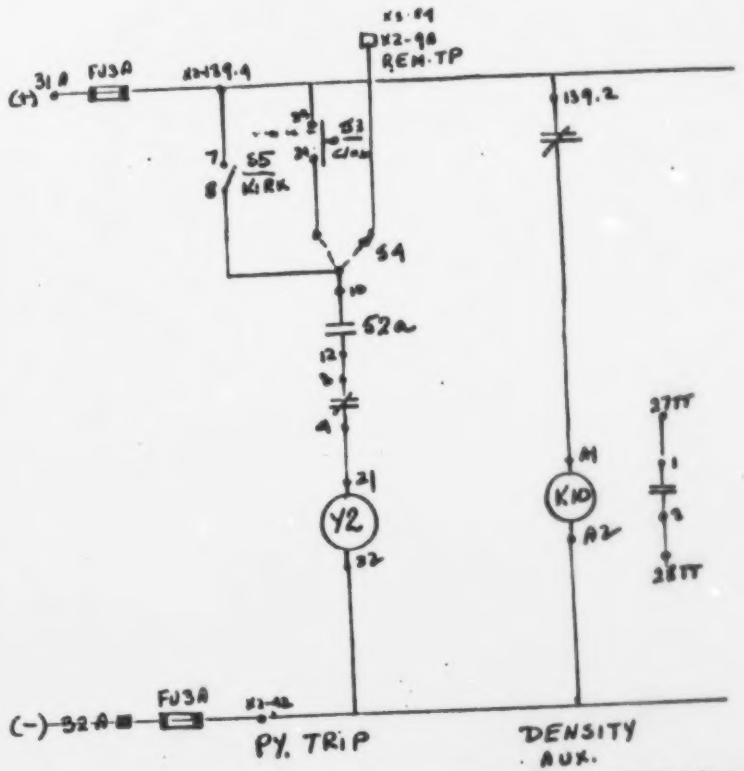
1) 5CB-L2 - local control switch is defective.
   - green light socket is broken.
2) 5CB-T1 - red light socket is defective.
   - trip coil A supervision light lamp socket is the wrong type.
3) 29T1 & 29T2 - Flexi Test Current blocks should be installed in place of potential type blocks.
4) D.C. Failure Agastat (Relay #80) not installed; not on site.
5) L2 Distance Relay is suspect. Recommend further discussion with the manufacturer.
6) B6T1 - lock-out relay missing.
7) All breaker - MOD interlocking keys not proved as all locks are being replaced.
8) Battery Charger #1 - high voltage alarm card appears defective.

(B) Comments & Recommendations:

1) Kirk interlocking switches are not shown on schematics. This will create difficulties in future troubleshooting.
2) Breaker Low SF6 gas operation blocking is not shown on breaker schematics, except on the manufacturer's prints.
3) We recommend making a breaker schematics "Canadian" style as per attached sketch.
   Such a schematic will greatly facilitate troubleshooting and understanding of breaker operation.
4) Battery charger instruction manual is not accurate. It appears to be general and does not cover details applicable to the installed chargers.

A. Kay/pj





K16 — 27SA — K1 — K2 — 28SA — ALARM —
K11 — 27C — K1 — K2 — 28C — SPARE

Y1 - Y2 - Trip Coils
Y3 - Close Coils.
K8 - Anti-pump Relay
K9 - Interlocking Relay (Sec. Trip / Py / Closing) } Gas Supervision
K10 - " "
K11 - " "
K16 - " Auxiliary

Note This dwg was made for ASEA diagram. Some terminal numbers do not agree with terminals on schematic diagrams made by INTEC

Schematic Diagram of
ASEA 50 KV SF6 BREAKER
B.C.R. SUB

CHIPPENDALE ELECTRICAL SERVICES LTD.

Report for: United Power Limited

Project: B.C. Rail Substation

Date: November 22, 1983

DOBLE TESTING

I have reviewed the Doble tests conducted by B.C. Hydro on our behalf and find all results to be satisfactory and within Doble tolerances.

David R. Chippendale, C.E.T.

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
BELMONT, MASS.
FORM DH-0617D

COMPANY B.C. RAIL — DATE 30 Sept 1983

LOCATION OF TESTS TUMBLER RIDGE — AIR TEMP. 10°C — OIL TEMP.

EQUIPMENT TESTED — WEATHER SUNNY — % HUM. 52

WESTINGHOUSE TYPE APT-69 — DATE LAST TEST — LAST TEST SHEET NO. ACCEPTANCE

H1-H2 = 55.2KV X1-X3 = 115v X2-X3 = 69v — 600:1 3 RATIO

Y1-Y3 = 115v Y2-Y3 = 69v — 480:1 3

COPIES TO STYLE = 06E5302

LINE NO	SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES: METER READING	MULTIPLIER	MICROAMPERES	WATTS: METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR. DF'S	HOT	GND	GUARD	UST	WINDING TYPE RATING
1	LK50663			SVT - L2											
2	P.F. = .35	10	71.5	.02	1.43	5.5	.01	.055	.38		H1H2	X1Y1			
3		10	78	10μ	780	24	.002	.048			H1H2		X1Y1		
4		10	67	10μ	670	8.5	.002	.017			H1H2			X1Y1	
5															
6		10	73	10μ	730	14	.002	.028			H1	X1Y1	H2		
7		10	73	10μ	730	14	.002	.028			H2	"	H1		
8															
9	EXT	10	52.5	10μ	525	μAmps					H1	X1Y1		H2	
10	EXT	10	52.5	10μ	525	μAmps					H2	"		H1	
11															
12			Ratio at 10KV						X1 - X3 = 20.5v			X2 - X3 = 12.3 v			
13									Y1 - Y3 = 20.5v			Y2 - Y3 = 12.3 v			
14															
15															
16	LK50662			SVT - L1											
17	P.F. = .43	10	71.5	.02	1.43	5.0	.01	.05	.35		H1H2	X1Y1			
18		10	78	10μ	780	20.5	.002	.041			H1H2		X1Y1		
19		10	66	10μ	660	8.5	.002	.017			H1H2			X1Y1	
20															
21		10	73	10μ	730	13.5	.002	.027			H1	X1Y1	H2		
22		10	73	10μ	730	13.5	.002	.027			H2	"	H1		
23															
24	EXT	10	52.5	10μ	525	μAmps					H1	X1Y1		H2	
25	EXT	10	52.5	10μ	525	μAmps					H2	"		H1	
26															
27			Ratio at 10KV						X1 - X3 = 20.6v			X2 - X3 = 12.4v			
28									Y1 - Y3 = 20.6v			Y2 - Y3 = 12.4v			
29															

REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY - M.G. SET

KEY TO INSULATION RATING

BUSHINGS: WITH STUDS-ETC.
0 = 0000
D = DETERIORATED
I = INVESTIGATE
B = BAD ENOUGH OR BEYOND

HOUSE DIVIDED-OIL-ETC.
00 = 0000
DD = DETERIORATED
II = INVESTIGATE
BB = BAD ENOUGH OR BEYOND

WINDINGS
00 = 0000
DD = DETERIORATED
II = INVESTIGATE
BB = BAD ENOUGH OR BEYOND

Total REN — SHEET NO.

INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

COMPANY B.C. RAIL DATE 1 OCT 1983

LOCATION OF TESTS TUMBLER RIDGE AIR TEMP. 6°C OIL TEMP.

EQUIPMENT TESTED T2 - LightWing Arrester Counter WEATHER O-CAST % HUM. 58

DATE LAST TEST

ASEA TXA N LB910001-A LAST TEST SHEET NO. ACCEPTANCE

LINE NO	BUSHING SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES: METER READING	MULTIPLIER	MICROAMPERES	WATTS: METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR. TO 20°C	NAMEPLATE RATING
1											
2			H1 - Counter								
3											
4			Operates from 2KV - 0.8 KV D.C								
5											
6			Counter left at 25								
7											
8											
9											
10			H2 - Counter								
11											
12			Operates from 2KV - 0.8 KV D.C								
13											
14			Counter left at 25								
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											
26											
27											
28											
29											

REMARKS

KEY TO NAMEPLATE RATING

TEST BY BEH CHECKED BY SHEET NO.

INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
WATERTOWN, MASS.
TYPE 69 WORKING DATA SHEET

COMPANY B.C. RAIL — DATE 1 OCT 1983

LOCATION OF TESTS TUMBLER RIDGE — AIR TEMP. 8°C — OIL TEMP.

EQUIPMENT TESTED 5FR-C1 — WEATHER SUNNY — % HUM. 55

MANF. - TRENCH ELECTRIC — DATE LAST TEST

50KV 250A 142.6 mH — LAST TEST SHEET NO. ACCEPTANCE

3.36 MVA

LINE NO	BUSHING SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES METER READING	MICROAMPERES MULTIPLIER	MICROAMPERES MICROAMPERES	WATTS METER READING	WATTS MULTIPLIER	WATTS WATTS	% POWER FACTOR MICROAMPERES	% POWER FACTOR WATTS	HOT	GND	GUD	UST	NAMEPLATE RATING
1															
2											H	C			
3		10	80	10x	800	10	.002	.020							
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															
27															
28															
29															

REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY — M.G. SET

SET TO INSULATION RATING

BUSHINGS - INSULATION - PCB
0 - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD PRIOR TO RECONDITIONING

HIGH REACTION - OIL - PCB
20 - GOOD
2D - DETERIORATED
2I - INVESTIGATE
2B - BAD PRIOR TO RECONDITIONING

BUSHINGS
90 - GOOD
9D - DETERIORATED
9I - INVESTIGATE
9B - BAD PRIOR TO RECONDITIONING

A
B
C
SUPPORT STR. →

49/24 REH — CHECKED BY _____ SHEET NO. _____

INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHING, INSTRUMENT TRANSFORMERS, ETC.)

COMPANY B.C. RAIL DATE 1 OCT 1983

LOCATION OF TESTS TUMBLER RIDGE AIR TEMP. 6 OIL TEMP.

EQUIPMENT TESTED 5VT-B1 WEATHER SUNNY % HUM. 54

MANUF - WESTINGHOUSE TYPE APF-69 DATE LAST TEST

HI-H2 = 55.2 KV X1-X3 = 115v X2-X3 = 69v LAST TEST SHEET NO. ACCEPTANCE

Y1-Y3 = 115v Y2-Y3 = 69v RATIO 800:1

STYLE - 05E5302 480:1

LINE NO	BUSHING SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS MICROAMPERES METER READING	MULTIPLIER	MICROAMPERES	WATTS METER READING	MULTIPLIER	WATTS	% POWER FACTOR MEASURED	CORR. 20°C	HOT	GND	GUD	UST	INSULATION RATING
1	LK5062 3			5VT-B1											
2	P.F. = .46%	10	73	.02	146	6.5	.01	.065	.45		Hi H2	X1 Y1			
3		10	79	10v	790	25	.002	.050			Hi H2		X1 Y1		
4		10	65	10v	650	9	.002	.018			Hi H2			Y1 Y1	
5															
6		10	73.5	10v	735	13	.002	.026			Hi	Y1 Y1	H2		
7		10	74.0	10v	740	18	.002	.036			H2	"	Hi		
8															
9	EXC	10	54	10v	540	μAMPS					Hi	X1 Y1		H2	
10	EXC	10	52	10v	540	μAMPS					H2	"		Hi	
11															
12			Ratio at 10KV					X1-Y3 =	20.3v	X2-X3 =	12.3v				
13								Y1-Y3 =	20.3v	Y2-Y3 =	12.3v				
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															
27															
28															
29															

REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY - M.G. SET

KEY TO INSULATION RATING

BUSHINGS - WITH STEPS - EXC.	BUSHINGS - NO STEPS - EXC.	REMARKS
G - GOOD	GG - GOOD	GG - GOOD
D - DETERIORATED	DD - DETERIORATED	DD - DETERIORATED
I - INVESTIGATE	II - INVESTIGATE	II - INVESTIGATE
B - BAD PACKING OR RECONDITION	BB - BAD PACKING OR RECONDITION	BB - BAD PACKING OR RECONDITION

REH

INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPACE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

BOSLE ENGINEERING COMPANY
BELMONT, MASS
TYPE OMEGA-MEG DATA SHEET

COMPANY B.C. RAIL DATE 1 Oct 1983

LOCATION OF TESTS TUMBLER RIDGE AIR TEMP. 6°C OIL TEMP.

EQUIPMENT TESTED SCT-T1 SCT-C1 WEATHER SUNNY % HUM. 54

MANUF - WESTINGHOUSE DATE LAST TEST

TYPE - OPC-69 STYLE 0SE5181 LAST TEST SHEET NO. ACCEPTANCE

Rated at 1200/600 : 5/5/5 Meter acc at 1200A - 60Hz = 0.3 B

LINE NO	BUSHING SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES METER READING	MICROAMPERES MULTIPLIER	MICROAMPERES MICROAMPERES	EQUIVALENT 10 KV READINGS: WATTS METER READING	WATTS MULTIPLIER	WATTS WATTS	% POWER FACTOR MEASURED	% POWER FACTOR CORR TO 20°C	HOT	GND	GUARD	UST	REMARKS
1	LK50624				SCT-T1										
2	P.F.=.31%														
3															
4		10	26.5	.1	2.65	3	.02	.06	.23		Hi H4	X1 Y1 Z1			
5		10	26.5	.1	2.65	3	.02	.06			Hi H4		X1 Y1 Z1		
6		10	0	0	0	0	0	0			Hi H4			X1 Y1 Z1	
7															
8															
9															
10	LK 50620				SCT-C1										
11	P.F.=.26%														
12															
13		10	26.5	.1	2.65	3.25	.02	.065	.25		Hi H4	X1 Y1 Z1			
14		10	26.5	.1	2.65	3.25	.02	.065			Hi H4		X1 Y1 Z1		
15		10	0	0	0	0	0	0			Hi H4			X1 Y1 Z1	
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															
27															
28															
29															

REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY - M.G. SET

KEY TO INSULATION RATING

BAD-NOT-REGULATORY-ETC.	BAD-BROKEN-OIL-ETC.	BAD
0-GOOD	20-GOOD	20-GOOD
D-DETERIORATED	20-DETERIORATED	20-DETERIORATED
I-INVESTIGATE	21-INVESTIGATE	21-INVESTIGATE
B-BAD BREAKDOWN OR REPAIRING	22-BAD BREAKDOWN OR REPAIRING	22-BAD BREAKDOWN OR REPAIRING

INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

BEAR ENGINEERING COMPANY
BELMONT, MASS
TYPE 5 HOLE DATA SHEET

COMPANY B.C. RAIL — DATE 1 OCT 1983
LOCATION OF TESTS TUMBLER RIDGE — AIR TEMP. 6°C — OIL TEMP.
EQUIPMENT TESTED 5CB-T1 5CB-C1 — WEATHER SUNNY — % HUM. 54
ASEA TYPE - HPL 145/2501 — DATE LAST TEST
145KV 2500A — LAST TEST SHEET NO. ACCEPTAN
SF_6 Gas Pressure at 20°C MAX = .7MPa — Built - 1983
Volume per Pole 90ℓ.

LINE NO	BUSHING SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES: METER READING	MICROAMPERES: MULTIPLIER	MICROAMPERES: MICROAMPERES	WATTS: METER READING	WATTS: MULTIPLIER	WATTS: WATTS	% POWER FACTOR: MEASURED	% POWER FACTOR: CORR. 20°C	HOT	GND	GND	UST	INSULATION RATING
1	7336-072				5CB - T1										
2														B	
3		10	3	10μ	30	1.5	.002	.003			A				
4		10	13	10μ	130	2	.002	.004			B	C			
5															
6															
7															
8					5CB - C1										
9														B	
10		10	3	10μ	30	1.0	.002	.001			A				
11		10	13.5	10μ	135	2	.002	.004			B	C			
12															
13															
14															
15															
16															
17															
18															
19															
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21															
22															
23															
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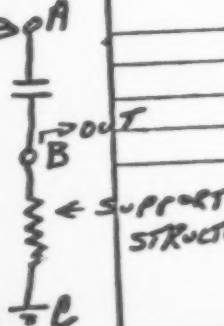
26															
27															
28															
29															

REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY - MG SET



KEY TO INSULATION RATING

BUSHINGS - INSULATION - KV
0 - GOOD
D - DETERIORATED
I - INVESTIGATE
D - BAD INCLUDE ON RECONDITIONS

BUSH. WINDING - PR - KV
GO - GOOD
DO - DETERIORATED
IO - INVESTIGATE
DO - BAD INCLUDE ON RECONDITIONS

WINDINGS
GG - GOOD
DG - DETERIORATED
IG - INVESTIGATE
DG - BAD INCLUDE ON RECONDITIONS

TYPE AM TEST SET NO. 69/24 TEST BY REH CHECKED BY _____ SHEET NO. _____

DOBLE INSULATION TESTS

THREE - WINDING TRANSFORMER

DOBLE ENGINEERING COMPANY BELMONT, MASS. Form No. 3H170

OIL ASKAREL GAS

COMPANY B.C. RAIL DIVISION DATE 20 Oct 1983

LOCATION OF TESTS TUMBLER RIDGE AIR TEMP. 9°C TOP OIL TEMP 9°C

TRANSFORMER T2 WEATHER SUNNY % HUMIDITY 49

MFR. C.G.E. SERIAL NO. 289579 A&E 1983 TYPE/CLASS ONAN/ONAF/FVA 25/33 at 65 KVA

FREE BREATHING ☐ SEALED ☐ GAS BLANKETED ☐ CONSERVATOR ☒ GALLONS OF OIL 21600 lbs.

	KV	MFR.	TYPE	KV CLASS	AMPS (NAME PLATE)	CAT. NO.	RATED KV	YEAR
1-Ø 230KV - 51.2/25.6	BUSHING	C.G.E	U	245 KV	600A	7700D	156 KV	
HIGH SIDE KV 230 Y☐ △☐		C.G.E	U	69 KV	1200A	6316-002	50 KV	
LOW SIDE KV 51.2 Y☐ △☐		CGE	U	69KV	1200A	6316-002	50 KV	
TERTIARY KV 51.2 Y☐ △☐								
NEUTRAL								

DATE LAST TEST

Customer's Order No. 80092 P.O. 722615-16 LAST SHEET NO. ACCEPTANCE

Lost MANUAL No. CGEI-4652 OVER-ALL TESTS EN-12890

TEST	TEST CONNECTIONS: WINDING ENERGIZED	WINDING GROUNDED	WINDING GUARDED	TEST KV	EQUIVALENT 10KV READINGS ON TAP #1: MILLIAMPERES: METER READING	MULTIPLIER	MILLIAMPERES	WATTS: METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR. 20°C	KEY TO INSULATION RATING: G = GOOD, D = DETERIORATED, I = INVESTIGATE, B = BAD (REMOVE OR RECONDITION)	INSULATION RATING
1	HIGH	X1+X2	T2T+X4 LOW AND TERT.	10	67.5	.2	13.5	3.5	.1	.35	—	—		
2	HIGH		LOW AND TERT.	10	78	.1	7.8	11.5	.02	.23	.29		C_H	
3	LOW	TERT.	HIGH	10	73	.2	14.6	40	.1	.40	—	—		
4	LOW		HIGH AND TERT.	10	71	.2	14.2	3.9	.1	.39	.27		C_L	
5	TERT.	HIGH	LOW	10	20	1	20	2.5	.2	.50	—	—		
6	TERT.		HIGH AND LOW	10	72	.2	14.4	4.0	.1	.40	.28		C_T	
7	ALL			10	36.5	1	36.5	5.0	.2	1.0	—	—	CHECK TEST (SHOULD EQUAL $C_H = C_L = C_T$)	
	CALCULATED RESULTS				—	—	5.7	—	—	.12			C_{HL} (TEST 1 MINUS TEST 2)	
					—	—	-.40	—	—	.01			C_{LT} (TEST 3 MINUS TEST 4)	
					—	—	5.6	—	—	.10			C_{HT} (TEST 5 MINUS TEST 6)	

BUSHING TESTS

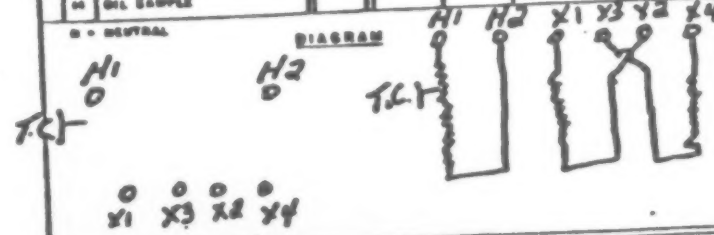
C_1

LINE NO.	BUSH NO.	GRADE	BUSHING SERIAL NO.	TEST KV	EQUIVALENT 10KV READINGS: MICROAMPERES: METER READING	MULTIPLIER	MICRO-AMPERES	WATTS: METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR. 20°C	COLLOID TESTS (WATTS/CURRENT): HOT — UST	CAP PLATE	CAP MEAS	INSULATION RATING
HIGH SIDE 1	H1		261105	10	77	.02	1.54	6.5	.01	.065	.42		TOP TAP	425	417	
2	H2		261337	10	78	.02	1.56	60	.01	.060	.38		TOP TAP	431	422	
3																
4	N															
LOW SIDE 5	X1		262933	10	54	.02	1.08	3.5	.01	.035	.32		TOP TAP	—	291	
6	X2		262915	10	53.5	.02	1.07	3.6	.01	.035	.33		" "	—	291	
7	X3		263283	10	54.5	.02	1.09	3.5	.01	.035	.32		" "	—	276	
8	X4		263282	10	56	.02	1.10	3.75	.01	.0375	.34		" "	—	295	
9																
10			UST	10	57	.1	5.7	9	.02	.18			C_{HL}			
11			UST	10	29.5	10	285	5.0	.002	.01			C_{TL}			
12	G		UST	10	57	.1	5.7	9	.02	.18			C_{HT}			
13											N/B					
14	OIL SAMPLE												OIL TEMP. °C			

NAME-PLATE B.P.F. .38 .39 .28 .28 .31 .32

G = NEUTRAL

DIAGRAM



REMARKS: FOR TEST PURPOSES (LOW WINDING = X1-X2 TERT = X3-X4)

BUSWORK DISCONNECTED

POWER SUPPLY - MG SET

TEST SET NO. 69/24 TEST BY REH CHECKED BY _____ SHEET NO. _____

DOBLE INSULATION TESTS

THREE - WINDING TRANSFORMER

OIL ASKAREL AIR GAS

COMPANY B.C. RAIL DIVISION DATE 20 OCT 1983

LOCATION OF TESTS TUMBLER RIDGE AIR TEMP. 9°C TOP OIL TEMP 9°C

TRANSFORMER T2 WEATHER SUNNY % HUMIDITY 49

MFR. G.E. SERIAL NO. 289579 AGE 1983 TYPE/CLASS KVA

FREE BREATHING ☐ SEALED ☐ GAS BLANKETED ☐ CONSERVATOR ☒ GALLONS OF OIL

HIGH SIDE KV Y☐ Δ☐

LOW SIDE KV Y☐ Δ☐

TERTIARY KV Y☐ Δ☐

NEUTRAL

BUSHINGS: MFR. TYPE CLASS DWG. NO. CAT. NO. KV YEAR

DATE LAST TEST

LAST SHEET NO.

COPIES TO

OVER-ALL TESTS

TEST	TEST CONNECTIONS: WINDING ENERGIZED	WINDING GROUNDED	WINDING GUARDED	TEST KV	EQUIVALENT 10KV READINGS: MILLIAMPERES METER READING	MILLIAMPERES MULTIPLIER	MILLIAMPERES	WATTS METER READING	WATTS MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	% POWER FACTOR: CORR. DEPT.	KEY TO INSULATION RATING: G = GOOD; D = DETERIORATED; I = INVESTIGATE; B = BAD (REMOVE OR RECONDITION)	INSULATION RATING
1	HIGH	LOW	TEST								— —	— —		
2	HIGH		LOW AND TEST										C_H	
3	LOW	TEST	HIGH								— —	— —		
4	LOW		HIGH AND TEST										C_L	
5	TEST	HIGH	LOW								— —	— —		
6	TEST		HIGH AND LOW										C_T	
7	ALL										— —	— —	CHECK TEST (SHOULD EQUAL $C_H + C_L + C_T$)	
CALCULATED RESULTS					— —	— —		— —	— —				C_H (TEST 1 MINUS TEST 2)	
					— —	— —		— —	— —				C_L (TEST 3 MINUS TEST 4)	
					— —	— —		— —	— —				C_T (TEST 5 MINUS TEST 6)	

BUSHING TESTS

LINE NO.	BUSH NO.	GROUND	BUSHING SERIAL NO	TEST KV	EQUIVALENT 10KV READINGS: MICROAMPERES METER READING	MICROAMPERES MULTIPLIER	MICROAMPERES	WATTS METER READING	WATTS MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	% POWER FACTOR: CORR. DEPT.	COLLAR TESTS (WATTS/CURRENT): HOT	UST	INSULATION RATING
HIGH SIDE 1			EXI	10	63	.2	12.6 mA	H.C. - TAP #1					H1	H2	
2			"	10	63.5	.2	12.7 mA	" " #1					H2	H1	
3			"	10	65	.2	13.0 mA	" TAP #2					H1	H2	
4	N		"	10	65	.2	13.0 mA	" " #2					H2	H1	
5			"	10	67	.2	13.4 mA	" TAP #3					H1	H2	
LOW SIDE 6			"	10	67.5	.2	13.5 mA	" " #3					H2	H1	
7			"	10	70	.2	14.0 mA	" TAP #4					H1	H2	
8	N		"	10	70.5	.2	14.1 mA	" " #4					H2	H1	
9			"	10	72	.2	14.4 mA	" TAP #5					H1	H2	
TERTIARY 10			"	10	72	.2	14.4 mA	" " #5					H2	H1	
11															
12	N														
13															
N	OIL SAMPLE														

(GND - TOP)

OIL TEMP. °C

G = NEUTRAL

DIAGRAM

REMARKS: HOT-TAP @ 2KV

									C2 PLATE pF	C2 Meas pF
Bushing										
H1	87	.02	1.74	40	.01	.M			433	465
H2	86	.02	1.72	3.0	.M	.03			428	460

DETAIL — R.E.H. CHECKED BY _____ SHEET NO. _____

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

DOBLE ENGINEERING COMPANY, BELMONT, MASS. FORM 00-DE170

(FORMERLY INSTRUMENT TRANSFORMERS, ETC.)

COMPANY B.C. RAIL — DATE 30 SEPT 1983

LOCATION OF TESTS TUMBLER RIDGE — AIR TEMP. 4°C — OIL TEMP.

EQUIPMENT TESTED 2VT-B1 — WEATHER SUNNY — % HUM. 59

MANF-WESTINGHOUSE TYPE-PCAY — DATE LAST TEST

230KV STACK CAP = 12500 pF — LAST TEST SHEET NO. = ACCEPTANCE

STYLE NO. 3905B82A67 — 1000 VA

COPIES TO 3CALQ559320D

LINE NO.	SERIAL NO.	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES METER READING	MULTIPLIER	MICROAMPERES	WATTS METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR 20°C	H V	G N D	G U S	U S T	Make	Meas Cap pF	Meas Capacitance of the Unit Tested	
					A-D													
1	521J83										A	C				12500	14540	
2		10	54	1	54	2	.2	.40			B	C		A		27100	27080	
3	135J83	10	50.5	2	101	.5	1	.5			B	C	A			27200	31160	
4	134J83	10	57	2	114	.5	1	.5										
5																		
6																		
7			RATIO AT 10KV.															
8			X_1-X_3 = 8.2v			Y_1-Y_3 =			8.2v		Z_1-Z_3 = 8.2v							
9			X_2-X_3 = 4.9			Y_2-Y_3 =			4.9v		Z_2-Z_3 = 4.9v							
10																		
11																		
12					B-D													
13	520J83										A	C				12500	14540	
14		10	55.5	1	55.5	2.5	.2	.50			B	C		A		27100	27100	
15	133J83	10	50	2	100	.25	1	.25			B	C	A			27300	31140	
16	132J83	10	57.5	2	115	.5	1	.50										
17																		
18																		
19			RATIO AT 10KV															
20			X_1-X_3 = 8.2v			Y_1-Y_3 = 8.2			Z_1-Z_3 = 8.2v									
21			X_2-X_3 = 4.9			Y_2-Y_3 = 4.9			Z_2-Z_3 = 4.9									
22																		
23					Acc. Class			RATIO										
24			X_1-X_3		0.3%			1200:1										
25			X_2-X_3		0.3%			2000:1										
26			Y_1-Y_3		0.3%			1200:1										
27			Y_2-Y_3		0.3%			2000:1										
28			Z_1-Z_3		1.2%			1200:1										
29			Z_2-Z_3		1.2%			2000:1										

1T serial #

STOCK NO.

STOCK NO.

2T serial #

1T STOCK NO.

2T STOCK NO.

2VT

A

VT

B

1T

REMARKS

BUSWORK DISCONNECTED

POWER SUPPLY - M.G. SET

GROUND SWITCH IN THE CLOSED POSITION

KEY TO INSULATION RATING

BUSHINGS-MAIN WINDING-ETC.
0-GOOD
D-DETERIORATED
I-INVESTIGATE
R-RECONDITIONED

WOOD WINDING-BLOCKS-ETC.
GD-GOOD
DD-DETERIORATED
ID-INVESTIGATE
RD-RECONDITIONED

WINDINGS
GW-GOOD
DW-DETERIORATED
IW-INVESTIGATE
RW-RECONDITIONED

9/24 REH

CHECKED BY

SHEET NO. 5

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
BELMONT, MASS.
FORM 904-METER

COMPANY B.C. RAIL — DATE 29 Sept 1983

LOCATION OF TESTS TUMBLER RIDGE — AIR TEMP. 8°C — OIL TEMP.

EQUIPMENT TESTED 2CB - L321 — WEATHER SUNNY — % HUM. 48

MANUF- ASEA TYPE HLR245/2502ER — DATE LAST TEST - -

SERIAL NO. 7346-062 — LAST TEST SHEET NO. ACCEPTANCE

253 KV 2500A GAS Pressure 0.3-0.7 MPA Built-1983

COPIES TO Mass of Oil - 300KG

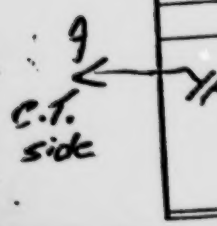
LINE NO	SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERED: METER READING	MULTIPLIER	MICROAMPERES	WATTS: METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR. 20°C	HOT	GND	GUST	CAP pF	INSULATION RATING
1					A-Ø										
2						7.0	.02	.14			B	C		A	809
3		10	30.5	.1	3.05						B	A		C	818
4		10	30.5	.1	3.05	6.5	.02	.13			B		AC		
5		10	19	10v	190	3	.002	.006							
6															
7															
8					B-Ø										
9						7.0	.02	.14			B	C		A	810
10		10	30.0	.1	3.00						B	A		C	819
11		10	30.0	.1	3.00	6.5	.02	.13			B		AC		
12		10	20	10v	200	3.5	.002	.007							
13															
14															
15					C-Ø										
16						7.5	.02	.15			B	C		A	811
17		10	30	.1	3.00						B	A		C	813
18		10	30	.1	3.00	6.5	.02	.13			B		AC		
19		10	21	10v	210	4.0	.002	.008							
20															
21															
22															
23															
24															
25															
26															
27															
28															
29															

INSTRUCTION MANUAL INDICATES GRADING CAP TO BE 800

REMARKS

BUSWORK DISCONNECTED
POWERSUPPLY - M.G. SET

C



KEY TO INSULATION RATING

BUSHINGS - INSULATION-POWER FACTOR
0 - 0.000
D - DETERIORATED
I - INVESTIGATE
R - BAD (REMOVE OR RECONDITION)

OTHER INSULATION-POWER FACTOR
0 - 0.000
D - DETERIORATED
I - INVESTIGATE
R - BAD (REMOVE OR RECONDITION)

RATINGS
0 - 0.000
D - DETERIORATED
I - INVESTIGATE
R - BAD (REMOVE OR RECONDITION)

19/24 TEST BY REH CHECKED BY _____ SHEET NO. _____

DOBLE INSULATION TESTS

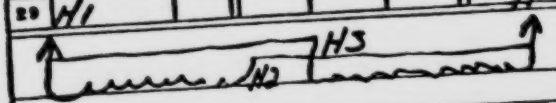
MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
BELMONT, MASS.
FORM DH-DE170

COMPANY B.C. RAIL (Tumbler Ridge) DATE 2 Oct 1983
LOCATION OF TESTS TUMBLER Ridge AIR TEMP. 6°C OIL TEMP.
EQUIPMENT TESTED 2CT1-L321 WEATHER Overcast % HUM. 58
DATE LAST TEST
MANUF - Westinghouse LAST TEST SHEET NO. ACCEPTANCE
TYPE - OPC-230 Rated current 600/300 5:5 Gals. of Oil = 160
230KV ACC on 600A = 0.3 B 2.0
COPIES TO STYLE - 05E5179

LINE NO	SERIAL NO.	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES: METER READING	MULTIPLIER	MICROAMPERES	EQUIVALENT 10 KV READINGS: WATTS: METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR. 20°C	HOT	GND	GUD	UST	INSULATION RATING
1	LK50546			A-G											
2	P.F. .41%										H1H4	X1Y1			
3		10	21	.1	2.1	2.75	.02	.055	.26		H1H4		X1Y1		
4		10	21	.1	2.1	2.75	.02				H1H4			X1Y1	
5		10													
6															
7															
8	547			B-G											
9	.42%										H1H4	X1Y1			
10		10	21	.1	2.1	2.75	.02	.055	.26		"		X1Y1		
11		10	21	.1	2.1	2.75	.02	.055			"			X1Y1	
12		10	0	0	0	0	0	0							
13															
14															
15	LK50545			C-G											
16	P.F. .41%										H1H4	X1Y1			
17		10	90	.02	1.80	7.0	.01	.07	.39		"		X1Y1		
18		10	80	.02	1.80	7.0	.01	.07			"			X1Y1	
19		10	0	0	0	0	0	0							
20															
21															
22															
23															
24															
25															
26															
27															
28							H4								
29	H1														



REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY - M.G. set

KEY TO INSULATION RATING

BUSHINGS - INSULATORS - ETC.
G - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD REMOVE OR RECONDITION

POWER TRANSFORMERS - REACTORS - ETC.
GOOD WINDINGS - OIL - ETC.
GD - GOOD
DD - DETERIORATED
ID - INVESTIGATE
BD - BAD REMOVE OR RECONDITION

WINDINGS
WG - GOOD
WD - DETERIORATED
WI - INVESTIGATE
WB - BAD REMOVE OR RECONDITION

TEST SET NO. 69/24 TEST BY REH CHECKED BY _____ SHEET NO. _____

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
BELMONT, MASS
FORM SM-METR

COMPANY B.C. RAIL — DATE 30 Sept 1983

LOCATION OF TESTS TUMBLER RIDGE — AIR TEMP. 10°C — OIL TEMP.

EQUIPMENT TESTED SCB-T2 SCB-L2 SCB-L1 — WEATHER SUNNY — % HUM. 53

ASEA TYPE - HPL/145/2501 — DATE LAST TEST

145 KV 2500 A — LAST TEST SHEET NO. ACCEPTANCE

SF6 Gas Pressure at 20°C MAX = .7 MPa = BUILT - 1983

COPIES TO Volume per pole 90 l.

LINE NO	SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES METER READING	MICROAMPERES MULTIPLIER	MICROAMPERES MICRO-AMPERES	WATTS METER READING	WATTS MULTIPLIER	WATTS WATTS	% POWER FACTOR: MEASURED	% POWER FACTOR: CORR 20°C	HOT	GND	GUD	UST	INSULATION RATING
1	7336-08				SCB - T2										
2															
3		10	3	10μ	30	1.5	.002	.003			A			B	
4		10	14	10μ	140	2.25	.002	.0045			B	C			
5															
6															
7	7336-09				SCB - L2										
8															
9		10	5	10μ	50	1.5	.002	.003			A			B.	
10		10	15	10μ	150	2.5	.002	.005			B	C			
11															
12															
13	7336-020				SCB - L1										
14															
15		10	3.5	10μ	35	1.5	.002	.003			A			B	
16		10	135	10μ	135	2.5	.002	.005			B	C			
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															
27															
28															
29															

A
B.

REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY - MG SET.

KEY TO INSULATION RATINGS

BUSHINGS - INSULATORS - ETC.
G - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD REMOVE OR RECONDITION

GOOD WINDINGS - OIL - ETC.
GD - GOOD
DD - DETERIORATED
ID - INVESTIGATE
BD - BAD REMOVE OR RECONDITION

WINDINGS
WG - GOOD
WD - DETERIORATED
WI - INVESTIGATE
WB - BAD REMOVE OR RECONDITION

TEST SET NO. 69/24 TEST BY REH CHECKED BY _____ SHEET NO. _____

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
WATERTOWN, MASS.
FORM DIN-METR

COMPANY B.C. RAIL — DATE 30 SEPT 1983

LOCATION OF TESTS TUMBLER RIDGE — AIR TEMP. 10°C — OIL TEMP.

EQUIPMENT TESTED SCT-T2 — WEATHER SUNNY — % HUM. 55

MANUF - WESTINGHOUSE — DATE LAST TEST —

TYPE - OPC-69 STYLE 0SE5181 — LAST TEST SHEET NO. ACCEPTANCE

Rated at 1200/600 : 5/5/5 — Meter acc at 1200A - 60Hz = 0.3B2

COPIES TO Oil Sols - 15

LINE NO	SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES METER READING	MICROAMPERES MULTIPLIER	MICROAMPERES	WATTS METER READING	WATTS MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	% POWER FACTOR: CORR 20°C	HOT	GND	GUD	GST	INSULATION RATING
1	LK50619														
2	P.F. = .28%														
3		10	28	.1	2.8	3.5	.02	.07	.25		H1 H4	X1 Y1 Z1			
4		10	27.75	.1	2.775	3.5	.02	.07			H1 H4		X1 Y1 Z1		
5		10	0	0	0	0	0	0			H1 H4			X1 Y1 Z1	
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
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19															
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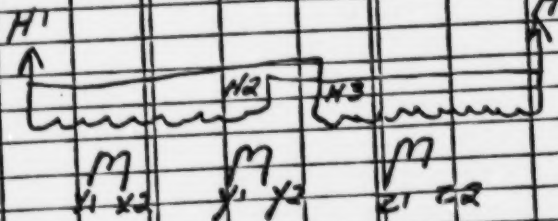
25															
26															
27															
28															
29															



REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY - MG. SET

KEY TO INSULATION RATING

BUSHINGS - PORCELAIN-ETC.
G - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD REMOVE OR RECONDITION

POWER WINDING-OIL-ETC.
GD - GOOD
DD - DETERIORATED
ID - INVESTIGATE
BD - BAD REMOVE OR RECONDITION

WINDINGS
WG - GOOD
WD - DETERIORATED
WI - INVESTIGATE
WB - BAD REMOVE OR RECONDITION

TEST SET NO. 69/24 TEST BY REH CHECKED BY SHEET NO.

...ON TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

...BELMONT, MASS.
TYPE SHIELDED DATA SHEET

COMPANY B.C. RAIL DATE 2 OCT 1983
LOCATION OF TESTS TUMBLER RIDGE AIR TEMP. 9°C OIL TEMP.
EQUIPMENT TESTED T2 - SURGE ARRESTERS WEATHER SUNNY % HUM. 52
DATE LAST TEST
MANUF - ASEA XAF. 192B LAST TEST SHEET NO. ACCEPTANCE
192 KV BUILT - 1983

LINE NO	BUSHING SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES METER READING	MICROAMPERES MULTIPLIER	MICROAMPERES MICRO-AMPERES	WATTS METER READING	WATTS MULTIPLIER	WATTS WATTS	% POWER FACTOR MEASURED	% POWER FACTOR CORR. 20°C	HOT	GND	GUD	UST	INSULATION RATING
1															
2	5343482	10	36	10N	360	21.5	.002	.043			B	A	C	C	
3		10	29	10N	290	18.5	.002	.037			B			C	
4		10	29.5	10N	295	22	.002	.044			D			C	
5		10	36	10N	360	23	.002	.046			D	E	C		
6															
7															
8															
9															
10	5343479	10	37.5	10N	375	22	.002	.044			B	A	C	C	
11		10	28.5	10N	285	17	.002	.034			B			C	
12		10	29.0	10N	295	22	.002	.044			D			C	
13		10	36	10N	360	23	.002	.046			D	E	C		
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															
27															
28															
29															

ON-H1

ON-H2

TOP

A

B

C

D

E

QUANTITY

REMARKS

BUSWORK CONNECTED
POWER SUPPLY - M.G. SET

KEY TO INSULATION RATING

BUSHINGS - INSULATION - KV.	2000 MEGOHMS - DRY - KV.	BUSHINGS
0 - 0000	20 - 0000	W0 - 0000
D - DETERIORATED	22 - DETERIORATED	WD - DETERIORATED
I - INVESTIGATE	21 - INVESTIGATE	WI - INVESTIGATE
R - BAD REMOVE OR RECONDITION	23 - BAD REMOVE OR RECONDITION	W3 - BAD (REMOVE OR RECONDITION)

...TEST SET NO. 69/21 TEST BY REH CHECKED BY _____ SHEET NO. _____

INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
BELMONT, MASS.
TYPE DOBLE DATA SHEET

COMPANY B.C. RAIL DATE 2 OCT 1983

LOCATION OF TESTS TUMBLER RIDGE AIR TEMP. 9°C OIL TEMP.

EQUIPMENT TESTED T2 - L.V. SURGE ARRESTER WEATHER SUNNY % HUM. 52

DATE LAST TEST

MANUF - OHIO BRASS SURGE ARRESTER LAST TEST SHEET NO. ACCEPTANCE

MAX Cont Volts - 58 KV RMS.

CATALOGUE NO. 216058

LINE NO	BUSHING SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS MICROAMPERES METER READING	MICROAMPERES MULTIPLIER	MICROAMPERES MICROAMPERES	WATTS METER READING	WATTS MULTIPLIER	WATTS WATTS	% POWER FACTOR CORRECTED	% POWER FACTOR WDG TEMP	HOT	GND	INSULATION RATING
1													
2											TOP	BTM	
3	52226	10	27	10	270	45.5	.01	.455					
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													

REMARKS

RISER - DISCONNECTED
POWER SUPPLY - M.G SET

KEY TO INSULATION RATING

DIELECTRIC-INSULATION-PFC

0 - GOOD
D - DETERIORATED
I - INVESTIGATE
O - BAD REMOVE OR RECONDITION

WOOD WORK-OIL-PFC

GD - GOOD
DD - DETERIORATED
II - INVESTIGATE
RO - BAD REMOVE OR RECONDITION

WINDING

GD - GOOD
DD - DETERIORATED
II - INVESTIGATE
RO - BAD REMOVE OR RECONDITION

TEST SET NO. 69/24 TEST BY REH CHECKED BY SHEET NO.

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY, BELMONT, MASS. FORM DIN-DIE178

COMPANY B.C. RAIL — DATE 30 Sept 1983

LOCATION OF TESTS TUMBLER RIDGE — AIR TEMP. 11°C — OIL TEMP.

EQUIPMENT TESTED 5CT-L2 — WEATHER SUNNY — % HUM. 52

See 5CT-52 for DATA — DATE LAST TEST

LAST TEST SHEET NO. ACCEPTANCE

COPIES TO

LINE NO.	SERIAL NO.	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES: METER READING	MICROAMPERES: MULTIPLIER	MICROAMPERES: MICROAMPERES	WATTS: METER READING	WATTS: MULTIPLIER	WATTS: WATTS	% POWER FACTOR: MEASURED	% POWER FACTOR: CORR. 20°C	H O T	G N D	G N D	U S T	INSULATION RATING
1	LK50618			5CT-L2											
2	PF=.25%										Hi Hv	x1 y1 z1			
3		10	25	.1	2.5	7.5	.02	.15	.60		Hi Hv		x1 y1 z1		
4		10	25	.1	2.5	7.25	.02				Hi Hv			x1 y1 z1	
5		10	0	0	0	0	0	0							
6															
7															
8	LK50617			5CT-L1											
9	PF=.25%										Hi Hv	x1 y1 z1			
10		10	26.5	.1	2.65	8.5	.02	.17	.64		Hi Hv		x1 y1 z1		
11		10	26.5	.1	2.65	8.5	.02	.17			Hi Hv			x1 y1 z1	
12		10	0	0	0	0	0	0							
13						Retested									
14															
15			2 Oct 1983			9°C			Overcast		% Hum = 56				
16															
17						5CT-L2									
18	LK50618														
19	P.F. .25%										Hi Hv	x1 y1 z1			
20		10	25	.1	2.5	3.5	.02	.07	.28		"		x1 y1 z1		
21		10	25	.1	2.5	3.5	.02	.07			"			x1 y1 z1	
22		10	0	0	0	0	0	0							
23															
24						5CT-L1									
25	LK50617														
26	P.F.=.25%										Hi Hv	x1 y1 z1			
27		10	25	.1	2.5	5.0	.02	.10	.40		"		x1 y1 z1		
28		10	25	.1	2.5	5.0	.02	.10			"			x1 y1 z1	
29		10	0	0	0	0	0	0							

REMARKS

BUSWORK DISCONNECTED
POWER SUPPLY - M.G. set

BUSHINGS - INSULATORS - ETC.
0 - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD REMOVE OR RECONDITION

KEY TO INSULATION RATING
DOOR BUSHINGS - OIL - ETC.
GD - GOOD
DD - DETERIORATED
RI - INVESTIGATE
RB - BAD REMOVE OR RECONDITION

WINDINGS
GD - GOOD
DD - DETERIORATED
RI - INVESTIGATE
RB - BAD REMOVE OR RECONDITION

69 | 24 TEST BY REH CHECKED BY _____ SHEET NO. _____

RESEARCH AND DEVELOPMENT
CHEMICAL RESEARCH DEPARTMENT
INSULATING OIL TEST REPORT

ASTM D-

PROJECT: 2911.71-83 0110 C4

LOCATION: Chippendale Elec. Services
REPORT TO: 3252 Beta Avenue
Imperial Square
Burnaby, B.C.
V5G 4K4

DATE RECEIVED: 12 October 1983
CC :

No.	Equipment	Sampled By	Sampled Date	Water P.P.M. D-1533	Dielectric KV. D-877	Dielectric KV. D-1816	I.F.T. D-971	Neut. No. D-664	Colour D-1500
1	2CT-1 A0	NR	NR	-	29		37.2	0.00	1.0
2	2CT-1 B0	NR	NR	-	36		41.6	0.01	1.0
3	2CT-1 C0	NR	29/9	-	33		40.6	0.00	1.0
4	5CT C1	NR	NR	-	45		35.8	0.00	1.0
5	5CT L1	NR	NR	-	39		39.2	0.01	1.0
6	5CT L2	NR	NR	-	35		44.6	0.01	1.0
7	5CT T1	NR	29/9	-	38		38.4	0.01	1.0
8	50 KVCT T2 (50619)	NR	NR	-	38		42.5	0.01	1.0
9	[redacted] T2 (289579)	NR	29/9	-	37		43.3	0.01	1.0
10	230 BRK RHS A0	NR	7/10	39	33		36.1	0.00	1.0
11	230 BRK RHS B0	NR	7/10	25	33		36.9	0.00	1.0
12	230 BRK RHS C0	NR	7/10	22	39		37.4	0.00	1.0
13	230 BRK LHS A0	NR	7/10	25	37		38.0	0.00	1.0
14	230 BRK LHS B0	NR	7/10	21	36		34.9	0.01	1.0
15	230 BRK LHS C0	NR	7/10	23	30		37.0	0.01	1.0

N.B.

REMARKS:

	Power Factor (D-924)	Inhibitor Content (D-2668)
1	0.58%	0.08%
2	0.48%	0.07%
3	0.54%	0.07%
4	0.98%	0.07%
5	0.74%	0.08%
6	0.82%	0.09%
7	0.55%	0.09%
8	0.91%	0.09%
9	0.72%	0.08%

N.B:- DO NOT USE THESE WATER RESULTS. REFER TO GAS-IN-01 REPORT 21 OCT 83 2911.73-83 0110 C.

TESTED BY: G.Hall/S.Hassanali

DATE: 17 October 1983

SIGNED: M Parniak

D73-240A(80/3)

72-240(08/73)

RESEARCH AND DEVELOPMENT
CHEMICAL RESEARCH DEPARTMENT
INSULATING OIL TEST REPORT

ASTM D-117

STATION Chippendale (CODE) PROJECT 2911.73-83 0110 C4

To Chippendale Electrical Services CC
3252 Beta Avenue
Burnaby PO No. C914-B

B.C.H. RECORD NO.		NR	NR	NR	NR	NR	NR
SAMPLE NO.		1286	1287	1288	1289	1290	1291
kV. VOLTAGE CLASS		230	230	230	230	230	230
POSITION DESIGNATION		AØRight	BØ Right	CØ Right	AØ Left	BØ Left	CØ Left
DATE SAMPLED		13-10-83	13-10-83	13-10-83	13-10-83	13-10-83	13-10-83
SAMPLE CODE		LNU	LNU	LNU	LNU	LNU	LNU
MANUFACTURER		NR	NR	NR	NR	NR	NR
SERIAL NO.		NR	NR	NR	NR	NR	NR
SAMPLED BY		ANK	ANK	NR	NR	NR	NR
		2CBL 321	2CBL 321	2CBL 321	2CB-L321	2CB-L321	2CB-L321
GAS CONTENT % V/V		13.0	0.014	13.0	13.2	13.4	13.2
% HYDROGEN (IN GAS)	H_2	0.003	0.002	ND	ND	ND	ND
OXYGEN	O_2	11.7	20.0	13.9	12.1	12.8	14.8
NITROGEN	N_2	87.3	79.8	85.7	87.4	86.7	84.6
CARBON MONOXIDE	CO	ND	ND	ND	ND	ND	ND
METHANE	CH_4	ND	ND	0.003	ND	0.004	0.004
CARBON DIOXIDE	CO_2	0.42	0.15	0.50	0.50	0.53	0.57
ACETYLENE	C_2H_2	ND	ND	ND	ND	ND	ND
ETHYLENE	C_2H_4	ND	ND	ND	ND	ND	ND
ETHANE	C_2H_6	ND	ND	ND	ND	ND	ND
H_2O PPM. W/W	D1533	19	19	16	18	17	14
kV BREAKDOWN	D 877						
kV BREAKDOWN (0.80 GAP)	D1816						
NEUT NO.	D 664						
IFT	D 971						
COLOUR	D1500						
INHIBITOR CONTENT	D2668						
POWER FACTOR	D 924						
PARTICLES	< 10 MICRONS						
	10-30 MICRONS						
	30-50 MICRONS						
	> 50 MICRONS						

REMARKS

TESTED BY A. Bergida DATE 21 October 1983 SIGNED M Dennis

D73-240(80/3)

RESEARCH AND DEVELOPMENT
CHEMICAL RESEARCH DEPARTMENT
INSULATING OIL TEST REPORT

ASTM D-117

STATION Chippendale (CODE) _____ PROJECT 2911.3.84 0110 C4

TO Chippendale Electrical Services Ltd
3252 Beta Avenue
Burnaby, B.C., V5G 4K4

CC _____

PO No. C914 (UP-BCR)

B.C.H. RECORD NO.		NR					
SAMPLE NO.		49					
KV. VOLTAGE CLASS		NR					
POSITION DESIGNATION		NR					
DATE SAMPLED		NR					
SAMPLE CODE		LNU					
MANUFACTURER		NR					
SERIAL NO.		NR					
SAMPLED BY		NR					
GAS CONTENT % V/V		4.1					
% HYDROGEN (IN GAS)	H_2	0.019					
OXYGEN	O_2	28.9					
NITROGEN	N_2	70.8					
CARBON MONOXIDE	CO	0.054					
METHANE	CH_4	0.008					
CARBON DIOXIDE	CO_2	0.29					
ACETYLENE	C_2H_2	0.007					
ETHYLENE	C_2H_4	0.010					
ETHANE	C_2H_6	ND					
H_2O PPM. W/W	D1533	8					
KV BREAKDOWN	D 877	Syr No.					
KV BREAKDOWN (0.80 GAP)	D1816	Z-8001					
NEUT NO.	D 664						
IFT	D 971						
COLOUR	D1500						
INHIBITOR CONTENT	D2668						
POWER FACTOR	D 924						
PARTICLES	< 10 MICRONS						
	10-30 MICRONS						
	30-50 MICRONS						
	> 50 MICRONS						

REMARKS TRANSFORMER T1

TESTED BY A. Bergida DATE 15 February 1984 SIGNED A. Bergida

RESEARCH AND DEVELOPMENT
CHEMICAL RESEARCH DEPARTMENT
INSULATING OIL TEST REPORT

ASTM D-11

PROJECT: 2911-4-83 0110 C4

LOCATION: Chippendale Elec. Services Ltd.
REPORT TO: 3252 Beta Avenue
Burnaby, B.C., V5G 4K4

DATE RECEIVED: 15 February 1984
cc :
PO No. C914

No.	EQUIPMENT	SAMPLED		WATER P.P.M.	DIELECTRIC KV.		I.F.T.	NEUT. NO.	COLOUR
		BY	DATE	D-1533	D-877	D-1816	D-971	D-664	D-1500
1	Oil Sample (T1)	NR	19/12						

REMARKS: Power Factor - 0.26%
Inhibitor Content - 0.07%

TESTED BY: G.Hall

DATE: 17 February 1984

SIGNED: D.R.

D73-240A(86/3)

CHIPPENDALE ELECTRICAL SERVICES LTD.

3252 BETA AVENUE, BURNABY, B.C. V5G 4K4

OIL TESTING REPORT

Customer: United Power Limited	Date: January 1984
Location: B.C. Rail, Tumbler Ridge Substation	Job No. C-914

A. Dielectric Test : Breakdown voltage in KV.
This test measures the insulating ability of the oil and is very sensitive to impurities, especially water. Recommended 22KV minimum.

B. Interfacial Tension : Dynes per centimeter.
This test measures soluble impurities, soluble contaminents and deterioration products. Recommended 17 dy/cm minimum.

C. Neutralization Number : Milligrams of KOH/gm of oil.
This test measures the acids present in the oil, usually the result of oxidation. Recommended 0.25 mg of KOH maximum.

D. Colour : Hellige.
Recommended 3 maximum.

			A.	B.	C.	D.
Sample#	Customer Identification	Serial No.	KV	IFT	Neut.	Colour
1	Transformer T1		37.4	35.0	0.2	0.75

Comments:

Tested by DC/AK

APPENDIX C

230/50 KV SUBSTATION - PROTECTION AND CONTROL

Omega Technical Services, Ltd.

1614-675 West Hasting Street
Vancouver, B.C., V6B 4W3
(604) 681-1068

FIELD TEST/COMMISSIONING REPORT

for

GLENAYRE 230/50KV CONTROL

AND METERING PANELS

at

B.C. RAIL'S TUMBLER RIDGE SUBSTATION

Omega Technical Services, Ltd.

1614-675 West Hasting Street
Vancouver, B.C., V6B 4W3
(604) 681-1068

The following Testing and Commission Report is only for the purpose of:

a) Proving only the function of Control and Protective Schemes as installed.
b) Calibrating and/or testing protective relays as outlined by manufacturer.

Coordination setting were provided by Canadian Pacific Consulting Ltd.,
- as shown by sheets provided - or as directed by Peter Biller.

It is <u>not</u> the intent of this report to prove the engineering design, functional design, correctness of the coordination study or compliance to prevailing codes and/or standards.

OMEGA TECHNICAL SERVICES LTD.

A.W. Griffith, C.E.T.

A) TESTING/CALIBRATING OF PROTECTIVE RELAYS

Protective relays were commissioned either as outlined by manufacturers procedures where provided, or by standard practices.

Auxillary relays were checked during the function checks of the panel.

All relays were checked for operation with 60% of rated D.C. Voltage applied.

Settings for relays were provided by Canadian Pacific Consulting Services Ltd.

1) Commissioning/Setting of Protective Relays

- See attached.

Field reports were provided on-site to P. Biller of C.P. Consulting Services Ltd. and to J. Popoff of B.C. Rail.

2) Deficiencies

i) As found results for relays removed from panels by Chippendale Electrical Services Ltd., or those who's blocking had been removed.

Relays are:

a) 50/51 - HVAØ
b) 87-T1
c) 87-T2
d) 67-T1-LV
e) 21-L1
f) 21-L2
g) 27-T1
h) 60A/60T
i) 59-L1
j) 59-L2

ii) 21-L2 Flag reset non-operative.

iii) 21-L1/21-L2 Relays cannot be set to coördination requirements - see manufacturers bulletins.

B. FUNCTIONAL TEST OF CONTROL/RELAYING SCHEMES

SCHEMES

1) Local Control & Protection Panel SP(L2)

a) Procedure

Each applicable "Loop", as related to this panel, shown on A.C. and/or D.C. schematic, was electrically operated and tested only to the related external panel terminals.

Where possible secondary injection was utilized to operate the protective and/or control devices during loop checks.

b) Deficiencies

i) Recloser Scheme

The recloser scheme was checked only on an individual loop basis. Functional operation, including field devices, which was originally planned, could not be performed. Field wiring (by others) from panel to related MODs and CBs was in a chaotic state, and was not functional when Omega left site.

ii) 43RC-L2

Requires off/on name plate.

c) Field Problems

Drawing WG9039 - 04 - 21

i) Wire too short to reach DAR on terminal X8 now on DAR X4.

ii) Diode network drawn incorrectly by Glenayre's representative. Should be between term 13-14 not 15-16 on X4.

iii) DBP (X8) too short; require new wire to be pulled in.

2) Local Control & Protection Panel SP (L1)

a) Procedure

Each applicable "Loop", as related to this panel, shown on A.C. and/or D.C. schematic, was electrically operated and tested only to the applicable external panel terminals.

Where possible secondary injection was utilized to operate the protective and/or control devices during loop checks.

b) Deficiencies

i) Recloser Scheme

The recloser scheme was checked only on an individual loop basis. Functional operation, including field devices, which was originally planned, could not be performed. Field wiring (by others) from panel to related MODSs and CBs was in a chaotic state, and was not functional when Omega left site.

ii) 43RC-L1

Requires off/on name plate.

c) Field Problems

Drawing WG9039 - 04 - 21

i) Diode network drawn incorrectly by Glenayre's representative. Should be between term 13-14 not 15-16 on X22.

3) Local Control & Protection Panel T2

a) Procedure

Each applicable "Loop", as related to this panel, shown on A.C. and/or D.C. schematic, was electrically operated and tested only to the applicable external panel terminals.

Where possible secondary injection was utilized to operate the protective and/or control devices during loop checks.

b) Deficiencies

i) Require C.T. shorting switch for terminals on 29-T2-LV blocking switch (Jumpers installed).

c) Field Problems

i) Installed 87-T1 (VAJX11) relay from adjacent panel in 86C1 slot.

ii) Jumpers between T.B. missing.

iii) Wire on 29-T2-BLK1 terminal #8 was marked DKB instead of DKH (was traced back).

4) Local Control & Protection Panel T1

a) Procedure

Each applicable "Loop", as related to this panel, shown on A.C. and/or D.C. schematic, was electrically operated and tested only to the applicable external panel terminals.

Where possible secondary injection was utilized to operate the protective and/or control devices during loop checks.

b) Deficiencies

i) Require C.T. shorting switches for terminals on 29-T1-LV blocking switch (Jumpers installed).

ii) Coil supervision Annunciator has no bulb and is any unique fixture.

iii) 87-T1 Relay missing - one name plate required.

c) Field Problems

Drawing #9039-04-24

i) No D.C. supply to frequency relay.
No ground wire on frequency relay.

ii) Wrong polarity on 67-T1-LV polarizing coil. BAU-8, BAV-7 not as given by owners representative.

5) Local Control & Protection Panel C.M.

a) Procedure

i) Metering loops were operationally checked by secondary injection (from panels incoming terminals). Each device was observed for output. No measurement of outputs for tranducers were taken.

ii) Each alarm point was "rung out" from source terminals to SCADA terminals. Also each Annunciator point was checked electrically from its source terminals.

iii) Operation of CBs/MODSs were simulated and indicating lights operationally checked.

iv) Master (T.R./SCADA) control switch was checked as loops were being operationally varified.

b) Deficiencies

i) Following meters do not show correct output.

a) L1 and L2 Ammeters, VAR/Wattmeter and associated recorders, do not indicate correct values. Name plate CT ratios of 1200/5 exists on Ammeters. Drawings indicate ratios of 600/5 required.

b) C1 Ammeter has name plate ratio of 300/5 drawing shows 600/5. Meter reading 1/2 of actual values.

ii) Following chart recorders damaged.

a) L1 - L2 kV Recorders - Pen transport support bent. Door appears to have had possible damage.

b) L321 kV Recorder also damaged as above. Also has stripped A.C. supply terminals.

iii) On/Off switch for chart recorders or kWH demand meters A/C supply required.

iv) Alarm annunciator panel does not give correct indication when picked up from "source" terminals.

a) T1 low oil level (71) is picked up by following field points:
- T1 low oil level (71)
- T1 high oil temp (26)
- T1 gas accumulation (63A)
- T1 high winding temp. (49-2)

b) T2 low oil level (71) is picked up by following points:
- T2 low oil level (71)
- T2 high oil temp (26)
- T2 gas accumulation (63A)
- T2 high winding temp. (49-2)

c) Could not obtain annunciation on following points:
i) 230 kV bus fault.
ii) 230 kV underfrequency.
iii) 230 kV undervoltage.

d) 50 kV bus/fault alarm is picked up by (59)(5VT-B1) overvoltage point.

e) Shunt capacitor current unbalance is picked up by (59)(5VT-132) overvoltage point.

v) Permanent A.C. supply to be wire into chart recorders and to terminals TB2-109 & 110 (BAE; BAF).

vi) Owners' representative voiced objection to location surface mounting of kWH demand meter. kWH meter mounted on inside end wall of panel.

vii) Two indicator lamp fixtures - damage in transit or on-site.

c) Field Problems

1) Master switch jumpers not shown on WG9039-04-25 - had to be installed after all external wiring installed to switch!!!

2) Discrepancy between termination on A.C. schematics and wiring grid for kWH demand. Also kWH meter terminals not as shown.

3) In several cases the field contractor, who installed interpanel connections, did not terminate wires as shown on wiring grid - hence problems existed with incomplete panel loops.

4) Interterminal jumpers missing in several locations.

5) "Short wires" in interpanel wiring harness could not be terminated as they were too short. There was no physical way these had been terminated or could be terminated at designated block. Interposing terminal blocks installed c/w jumpers.

6) Following problems existed in alarm wiring.

   i) "Shorts" between adjacent terminals in SCADA T.B. caused by strands touching.

   ii) Wires loose in blocks or terminated on insulation.

   iii) DSU (TB2A-180) and DST (TB2A-181) interposed c/w wrong I.D. numbering.

7) Several wires with wrong I.D. numbers on SCADA/T.R. master switch.

8) Wire missing from master switch (DCG).

9) DRF moved from F5 to C5 on master switch to enable annunciator acknowledge (SCADA). (Done by others.)

TEST REPORT
PERCENTAGE DIFFERENTIAL RELAY (HARMONIC RESTRAINT)

RCUIT LOCATION B C Rail - Tumbler
.LAY 30 Differential
MFG. GEC TYPE DIH 31 DEA 4C
C.T. RATIO
RANGE
TIME OPERATIONS INDICATOR Shunt AMPS.
IL NO.

CIRCUIT DESIGNATION Protection L1
PHASE OR LOCATION IN PANEL T1
STYLE NO. FUNCTION 87 T1
P.T. RATIO
PICKUP
INSTAN. OPERATIONS INDICATOR AMPS.

			SPEC	AØ AS FOUND	AØ AS LEFT	BØ AS FOUND	BØ AS LEFT	CØ AS FOUND	CØ AS LEFT
SETTINGS	TAP	Wdg #1	N/A	–	–	–	–		
		Wdg #2	N/A	–	–	–	–		
		Wdg #3	N/A	–	–	–	–		
	SLOPE		30%	15	30	15	30		
	INST								
RELAY	PICK-UP	FRONT ~~BACK~~	0.15	0.72	0.72	0.75	0.75		
	TMG	VALUE	2 x PU	2 x	2 x	2 x	2 x		
		TIME		53.1 ms	53.1 ms	43.9 ms	43.9 ms		
TESTS	THRU FAULT	VALUE		40	40	40	40		
		RESTRAINT OR OPERATE?		OK	OK	OK	OK		
	SLOPE	I oper	3.0	2.6	3.6	2.9	3.7		
		I Rest	10.0	10.0	10.0	10.0	10.0		
	Io / IR x 100		30%		36%		37%		
	INST. PICK-UP		50	52	52	51	51		
	TARGET (D.C.) PICK-UP		Shunt	OK	OK	OK	OK		
	HARMONIC RESTRAINT (2nd)		> 20%	> 19%	> 19%	> 19%	> 19%		
	DATE				Oct 83		Oct 83		
	TECHNICIAN				FLN		FLN		

REMARKS: Serial No. 089439N; AØ 1st Term 11-12-14; BØ 1st Term 15-16-12; Restraint with 3rd Harmonic Filter To 2nd

TEST REPORT
PERCENTAGE DIFFERENTIAL RELAY (HARMONIC RESTRAINT)

RCUIT LOCATION B.C. Rail - Tumbler
LAY 3Ø Differential
MFG. GEC TYPE DTH 31 DiA 4C
C.T. RATIO
RANGE
TIME OPERATIONS INDICATOR AMPS.
IL NO.

CIRCUIT DESIGNATION Protection L2
PHASE OR LOCATION IN PANEL T2
STYLE NO. FUNCTION 87 T2
P.T. RATIO
PICKUP
INSTAN. OPERATIONS INDICATOR AMPS.

			SPEC	AØ AS FOUND	AØ AS LEFT	BØ AS FOUND	BØ AS LEFT	CØ AS FOUND	CØ AS LEFT
SETTINGS RELAY TESTS	TAP	Wdg #1	N/A	—	—	—	—		
		Wdg #2	N/A	—	—	—	—		
		Wdg #3	N/A	—	—	—	—		
	SLOPE		30%	15%	30%	15%	30%		
	INST								
	PICK-UP	FRONT ~~BACK~~	0.75	0.76	0.76	0.76	0.76		
	TMG	VALUE	2×PU	2×	2×	2×	2×		
		TIME		51.6ms	51.6ms	51.2 ms	51.2ms		
	THRU FAULT	VALUE		40	40	40	40		
		RESTRAINT OR OPERATE?		OK	OK	OK	OK		
	SLOPE	I oper	3.0	2.1	3.7	2.1	3.5		
		I Rest	10.0	10.0	10.0		%		
	$\frac{Io}{IR} \times 100$		30%	21%	37%	21%	35%		
	INST. PICK-UP		50	52	52	52	52		
	TARGET (D.C.) PICK-UP		SHUNT						
	HARMONIC RESTRAINT 2nd		>20%	>19%	>19%	>19%	>19%		
	DATE								
	TECHNICIAN								

REMARKS: Serial No. 088440 N; Aø Is Term 11-12-14; Bø Is Term 15-16-18; Restraint With 3rd Harmonic Similar To Rest.

TEST REPORT

DIRECTIONAL OVERCURRENT INSPECTION AND TEST RECORD

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY
MFG. G E C TYPE CCDE23PF2250BG
C.T. RATIO
TAP RANGE AMPS.
TIME OPERATIONS INDICATOR SHUNT
IL NO.

CIRCUIT DESIGNATION PROTECTION T1
PHASE OR LOCATION IN PANEL T1-LV
STYLE NO. FUNCTION 67-T1-LV
P.T. RATIO
INSTANTANEOUS
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION	SETTINGS			RELAY TESTS										
	TAP	APPROX TIME DIAL	INST.	DIRECTIONAL ELEMENT PICK-UP			OVERCURRENT ELEMENT		INST. ELEMENT	TARGET (DC)	DC CONTACTOR SWITCH	DATE	INT.
				AMPS	VOLTS	ANT	PICK UP	TIME 4X PICK-UP	PICK-UP	PICK-UP			
SPECIFICATIONS	1	0.1	N/A	*	*	60°	105%	*	N/A	SHUNT			
A0 AS FOUND				2.0	0.5	60°	1.02	0.375sec		OK			
AS LEFT				2.0	0.5	60°	1.02	0.375sec		OK		Oct 23	EGH
B0 AS FOUND													
AS LEFT													
C0 AS FOUND													
AS LEFT													
N/O SPECIFICATIONS													
AS FOUND													
AS LEFT													

REMARKS: SERIAL No 090507N - *No SPECIFICATIONS GIVEN.

TEST REPORT

DIRECTIONAL OVERCURRENT INSPECTION AND TEST RECORD

CIRCUIT LOCATION: BC RAIL - TUMBLER RIDGE
RELAY
MFG.: GEC TYPE: CCD 23 PF2250 B6
C.T. RATIO
TAP RANGE
TIME OPERATIONS INDICATOR: SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION: PROTECTION T2
PHASE OR LOCATION IN PANEL: T2-LV
STYLE NO. FUNCTION: 67-T2-LV
P.T. RATIO
INSTANTANEOUS AMPS.
INSTAN. OPERATIONS INDICATOR

CONDITION	SETTINGS			RELAY TESTS										
	TAP	APPROX TIME DIAL	INST.	DIRECTIONAL ELEMENT PICK-UP			OVERCURRENT ELEMENT		INST. ELEMENT	TARGET (DC)	DC CONTACTOR SWITCH	DATE	INT.
				AMPS	VOLTS	ANT	PICK UP	TIME 4X PICK-UP	PICK-UP	PICK-UP			
SPECIFICATIONS	1	0.1	N/A	*	*	60°	105%	*	N/A	SHUNT			
A0 AS FOUND				2.0	0.6	59°	0.95	0.355sec	—			02-93	FLH
AS LEFT				2.0	0.6	59°	1.03	0.35	—	OK			
B0 AS FOUND													
AS LEFT													
C0 AS FOUND													
AS LEFT													
N/G													
SPECIFICATIONS													
AS FOUND													
AS LEFT													

REMARKS: SERIAL No 090508N - *No SPECIFICATIONS GIVEN

TEST REPORT
UNDER/OVER VOLTAGE RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY INSTANTANEOUS UNDER VOLTAGE
MFG. GEC TYPE VAG 70 AF 98A
C.T. RATIO
TAP RANGE AMPS.
TIME OPERATIONS INDICATOR
IL NO.

CIRCUIT DESIGNATION L2
PHASE OR LOCATION IN PANEL L2
STYLE NO. FUNCTION 27AR-L2
P.T. RATIO
INSTANTANEOUS
INSTAN. OPERATIONS INDICATOR SHUNT AMPS.

CONDITION	SETTINGS: TAP VOLTS	SETTINGS: TIME DIAL	SETTINGS: INST. VOLTS	RELAY TESTS: D.O. PICK-UP AMPS LIMITS ----	RELAY TESTS: 115 V T. 90% x TAP LIMITS ---- SEC. CYCLES	RELAY TESTS: x TAP LIMITS ---- SEC. CYCLES	RELAY TESTS: x TAP LIMITS ---- SEC. CYCLES	RELAY TESTS: INST. VOLTS	RELAY TESTS: TARGET OPER. AMPS DC ICS	OI	RELAY TESTS: 500V INSUL TEST MEGOHMS	RELAY TESTS: DATE	RELAY TESTS: INT.
SPECIFICATIONS			72.9										
A∅ AS FOUND				NOT	5ST				OK		—	OCT 93	FLN
AS LEFT				77	0.061								
B∅ AS FOUND													
AS LEFT													
C∅ AS FOUND													
AS LEFT													

REMARKS: SERIAL No. 024709 P

TEST REPORT
UNDER/OVER VOLTAGE RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY INSTANTANEOUS UNDER VOLTAGE
MFG. G.E.C. TYPE VAG 70 AF 99A
C.T. RATIO
TAP RANGE
TIME OPERATIONS INDICATOR AMPS.
IL NO.

CIRCUIT DESIGNATION L1
PHASE OR LOCATION IN PANEL L1
STYLE NO. FUNCTION 27AR-L1
P.T. RATIO
INSTANTANEOUS
INSTAN. OPERATIONS INDICATOR SHUNT. AMPS.

CONDITION		SETTINGS			RELAY TESTS									
		TAP VOLTS	TIME DIAL	INST. VOLTS	D.O. PICK-UP AMPS LIMITS ---	115V to 90% x-TAP: LIMITS ---- SEC. CYCLES	x TAP: LIMITS ---- SEC. CYCLES	x TAP: LIMITS ---- SEC. CYCLES	INST. VOLTS	TARGET OPER. AMPS DC ICS / OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS				72.9									
A∅	AS FOUND					Not Set				OK	—	OCT 83	I-LN
	AS LEFT				73	0.06							
B∅	AS FOUND												
	AS LEFT												
C∅	AS FOUND												
	AS LEFT												

REMARKS: SERIAL No. 024710 P

TEST REPORT
UNDER/OVER VOLTAGE RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY TIME OVERVOLTAGE
MFG. GEC TYPE VDG11AB121B6.
C.T. RATIO
TAP RANGE
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION L2
PHASE OR LOCATION IN PANEL L2.
STYLE NO. FUNCTION 59-L2
P.T. RATIO
INSTANTANEOUS N/A
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION		SETTINGS			RELAY TESTS									
		TAP VOLTS	TIME DIAL	INST. VOLTS	PICK-UP AMPS LIMITS ----	0 TO 140% x TAP: LIMITS ---- SEC. CYCLES	x TAP: LIMITS ---- SEC. CYCLES	x TAP: LIMITS ---- SEC. CYCLES	INST. VOLTS	TARGET OPER. AMPS DC ICS / OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS		121		N/A		10.4							
A0	AS FOUND				130								
	AS LEFT				126	10.6	-	-	-	OK	INFT	Oct 93	CLN
B0	AS FOUND												
	AS LEFT												
C0	AS FOUND												
	AS LEFT												

REMARKS: SERIAL NUMBER 088479N

TEST REPORT
UNDER/OVER VOLTAGE RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY
MFG. GEC TYPE VDG 11A2121B6
C.T. RATIO
TAP RANGE
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION L1
PHASE OR LOCATION IN PANEL L1
STYLE NO. FUNCTION 59-61
P.T. RATIO
INSTANTANEOUS N/A
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION		SETTINGS			RELAY TESTS									
		TAP VOLTS	TIME DIAL	INST. VOLTS	PICK-UP AMPS ±LIMITS ---	OT 140 =TAP: LIMITS ---- SEC. CYCLES	x TAP: LIMITS ---- SEC. CYCLES	x TAP: LIMITS ---- SEC. CYCLES	INST. VOLTS	TARGET OPER. AMPS DC ICS / OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS		121	—	N/A	125	10			N/A	—	OK			
AB	AS FOUND		1.0		51.1	—			—	OK	INFCT	Oct 93	CLN
	AS LEFT		1.0		126	13.9							
BB	AS FOUND												
	AS LEFT												
CB	AS FOUND												
	AS LEFT												

REMARKS: SERIAL No. 0B8478N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY STATIC
MFG. GEC TYPE CTG 25NG1006D6
C.T. RATIO
TAP RANGE 2.5 - 10 (50 - 200%)
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION
PHASE OR LOCATION IN PANEL C1
STYLE NO. FUNCTION 50/51 C1
P.T. RATIO
INSTANTANEOUS 2 - 8 x
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS ----	4 x TAP: A. LIMITS ---- SEC. CYCLES	6x TAP: A. LIMITS ---- SEC. CYCLES	x TAP: A. LIMITS ---- SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	2.5		4x	. .	15	2	—					
AØ AS FOUND				2.5	11.2	0.9314	—					
AS LEFT				2.5	11.2	0.5314		10.1	OK	—	Oct 83	FLN
BØ AS FOUND												
AS LEFT												
CØ AS FOUND												
AS LEFT												
N/G												
SPECIFICATIONS												
AS FOUND												
AS LEFT												

REMARKS: SERIAL No. 092265N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION B.C. RAIL - TUMBLER RIDGE
RELAY STATIC
MFG. GEC TYPE CTIG 19NG2U02 D6
C.T. RATIO
TAP RANGE AMPS.
TIME OPERATIONS INDICATOR
IL NO.

CIRCUIT DESIGNATION
PHASE OR LOCATION IN PANEL C1
STYLE NO. FUNCTION 50 BF C1
P.T. RATIO
INSTANTANEOUS AMPS.
INSTAN. OPERATIONS INDICATOR SILV.F

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS ---	2 x TAP: A. LIMITS --- SEC. CYCLES	x TAP: A. LIMITS --- SEC. CYCLES	x TAP: A. LIMITS --- SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS	TARGET OPER. AMPS DC OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS				5.0									
A# AS FOUND				N.F SET					OK		—	Oct 93	IRLH
AS LEFT				5.0	20.0MS								
B# AS FOUND													
AS LEFT													
C# AS FOUND													
AS LEFT													
N/G													
SPECIFICATIONS													
AS FOUND													
AS LEFT													

REMARKS: SERIAL No. 088486N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION BC RAIL - TUMBLE RIDGE
RELAY STATIC
MFG. G E C TYPE CTIG19NG2002DG
C.T. RATIO
TAP RANGE
TIME OPERATIONS INDICATOR AMPS.
IL NO.

CIRCUIT DESIGNATION PROTECTION LP
PHASE OR LOCATION IN PANEL LP
STYLE NO. FUNCTION 50 BF - LP
P.T. RATIO
INSTANTANEOUS
INSTAN. OPERATIONS INDICATOR SHUNT. AMPS.

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS ----	2 x TAP: A. LIMITS ---- 4 SEC. ~~CYCLES~~	x TAP: A. LIMITS ---- SEC. CYCLES	x TAP: A. LIMITS ---- SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS			7.0									
AØ AS FOUND			N.T.	SAT					OK	—	Jul 93	FLN
AS LEFT			7.0		20.0A3							
BØ AS FOUND												
AS LEFT												
CØ AS FOUND												
AS LEFT												
N/G												
SPECIFICATIONS												
AS FOUND												
AS LEFT												

REMARKS: SERIAL No. 0884871N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY STATIC
MFG. G E C TYPE CTIG 19NG2002D6
C.T. RATIO
TAP RANGE AMPS.
TIME OPERATIONS INDICATOR
IL NO.

CIRCUIT DESIGNATION PROTECTION L1
PHASE OR LOCATION IN PANEL L1
STYLE NO. FUNCTION 50 BF - L1
P.T. RATIO
INSTANTANEOUS AMPS.
INSTAN. OPERATIONS INDICATOR SHUNT

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS ----	2 x TAP: A. LIMITS ---- SEC. CYCLES	x TAP: A. LIMITS ---- SEC. CYCLES	x TAP: A. LIMITS ---- SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS			7.0									
AØ AS FOUND			N.T	SAT.					OK	—		FLH
AS LEFT			7.0		20.0 MSEC							
BØ AS FOUND												
AS LEFT												
CØ AS FOUND												
AS LEFT												
N/G												
SPECIFICATIONS												
AS FOUND												
AS LEFT												

REMARKS: SERIAL No. 089485N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY VERY INVERSE
MFG. GEC TYPE CDG 23 AF2610 BX6
C.T. RATIO
TAP RANGE 2.5 - 10
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION PROTECTION L2
PHASE OR LOCATION IN PANEL L2
STYLE NO. FUNCTION 50/51 - L1
P.T. RATIO
INSTANTANEOUS 10 - 40
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION	SETTINGS: TAP AMPS	SETTINGS: TIME DIAL	SETTINGS: INST. AMPS	RELAY TESTS: PICK-UP AMPS LIMITS ----	2 x TAP: A. LIMITS ---- SEC. CYCLES	5 x TAP: A. LIMITS ---- SEC. CYCLES	10 x TAP: A. LIMITS ---- SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS	TARGET OPER. AMPS DC OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	7.5	0.1	15	7.1-7.89	3.2	0.52	0.31						
A∅ AS FOUND				7.8	3.23	0.52	0.31	15	OK		Inf Ω	OCT 83	FLH
A∅ AS LEFT				7.8	3.23	0.52	0.31						
B∅ AS FOUND													
B∅ AS LEFT													
C∅ AS FOUND													
C∅ AS LEFT													
N/G													
SPECIFICATIONS													
AS FOUND													
AS LEFT													

REMARKS: SERIAL No. 088481 N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
RELAY VERY INVERSE
MFG. G E C TYPE CDG 83 AF 26 G10 BX6
C.T. RATIO
TAP RANGE 2.5 - 10
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION L1
PHASE OR LOCATION IN PANEL L1
STYLE NO. FUNCTION 50/51 - L1
P.T. RATIO
INSTANTANEOUS 10 - 40
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS ----	2 x TAP: A. LIMITS ---- SEC. CYCLES	5 x TAP: A. LIMITS ---- SEC. CYCLES	10 x TAP: A. LIMITS ---- SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS	TARGET OPER. AMPS DC OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	7.5	0.1	15	7.7 - 7.8	3.2	0.52	0.31						
AØ AS FOUND				8.2	NOT TAKEN								
AS LEFT				7.7	3.04	0.51	0.31	15	OK		1000 +	OCT 93	-1-2 H
BØ AS FOUND													
AS LEFT													
CØ AS FOUND													
AS LEFT													
N/G													
SPECIFICATIONS													
AS FOUND													
AS LEFT													

REMARKS: SERIAL No. 088480 N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION BC RAIL · TUMBLER RIDGE
RELAY VERY INVERSE
CFG. GLC TYPE CDG 23 AF 611 BX6
P.T. RATIO
TAP RANGE 2.5 - 10 ; 0.5 - 2
TIME OPERATIONS INDICATOR SHUNT AMPS.
OIL NO.

CIRCUIT DESIGNATION PROTECTION T1
PHASE OR LOCATION IN PANEL T1
STYLE NO. FUNCTION 50/51-T1
P.T. RATIO
INSTANTANEOUS 20 - 80 ; 2 - 8
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS ----	2 x TAP: A. LIMITS ---- SEC. ~~CYCLES~~	5 x TAP: A. LIMITS ---- SEC. ~~CYCLES~~	10x TAP: A. LIMITS ---- SEC. ~~CYCLES~~	INST. AMPS	TARGET OPER. AMPS DC ICS OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	7.5	0.7	25	7.65 - 7.35	6.7	1.04	0.60					
A@ AS FOUND				7.7	6.12	1.01	0.60	24.2				
AS LEFT				7.7	6.12	1.01	0.60	24.2	OK	1000+	OCT 93	I-LN
B@ AS FOUND				7.9								
AS LEFT				7.7	6.55	1.03	0.60	24.5	OK.	1000+	OCT 93	FLN
C@ AS FOUND												
AS LEFT												
N@ TYP: CDG 23 AF-E				06 03 x 6								
SPECIFICATIONS	1.2	0.1	5	1.22 - 1.24	1.6	0.26	0.13					
AS FOUND				1.23	1.43	0.26	0.17					
AS LEFT				1.23	1.43	0.26	0.17	5.0	OK	1000+	OCT 93	I-LN

REMARKS: SERIAL NUMBERS A@ 088459 N; B@ 088462 N ; NEUTRAL 088466N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION B.C RAIL - TUMBLER RIDGE
RELAY VERY INVERSE
MFG. GEC TYPE CDG 23 AF 611 BX6
C.T. RATIO
TAP RANGE 2.5-10 / 0.5-2.0
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION PROTECTIVE T1
PHASE OR LOCATION IN PANEL HV
STYLE NO. FUNCTION 50/51-HV
P.T. RATIO
INSTANTANEOUS 10-40 / 2-8
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS	2 x TAP: A. LIMITS SEC. ~~CYCLES~~	5 x TAP: A. LIMITS SEC. ~~CYCLES~~	10x TAP: A. LIMITS SEC. ~~CYCLES~~	INST. AMPS	TARGET OPER. AMPS DC ICS OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	7.5	0.5	17	7.65-7.73	8.0	1.33	0.7					
AØ AS FOUND				7.7	7.2	1.66	0.73	17.3	OK.	1000+	OUT 83	FLH
AS LEFT				7.7	7.2	1.66	0.73					
BØ AS FOUND				8.0								
AS LEFT				7.7	8.17	1.3	0.75	17.2	OK	1000+	OUT 83	FLH
CØ AS FOUND												
AS LEFT												
N/Ø TYPE CDG 23 AT-P 616 BX6												
SPECIFICATIONS	1.2	0.5	6	1.22-1.24	7.21	1.24	0.74	6.0				
AS FOUND				1.24	7.21	1.24	0.74	6.0	OK	1000+	OUT 83	FLH
AS LEFT				1.24								

REMARKS: SERIAL No.- AØ 088458N ; BØ 088460N ; NEUTRAL 088465N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION B.C. RAIL - TUMBLER RIDGE
RELAY VERY INVERSE
MFG. GEC TYPE CDG 13 AF 2162 AG
C.T. RATIO
TAP RANGE P.5 - 10
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION PROTECTION T-2
PHASE OR LOCATION IN PANEL T2 - LV
STYLE NO. FUNCTION 51 - T2 - LV
P.T. RATIO
INSTANTANEOUS N/A
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS	2x TAP: A. LIMITS SEC. CYCLES	5x TAP: A. LIMITS SEC. CYCLES	10x TAP: A. LIMITS SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS	TARGET OPER. AMPS DC OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	10	0.2	N/A	10.3 - N.S	3.2	0.53	0.3	—					
AB · AS FOUND				10.4	3.07	0.51	0.31	-	OK		1000+	OCT 93	1ST LN
AS LEFT				10.4	3.07	0.51	0.31	-					
BB AS FOUND													
AS LEFT													
CB AS FOUND													
AS LEFT													
N/G													
SPECIFICATIONS													
AS FOUND													
AS LEFT													

REMARKS:

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION BC RAIL - TUMBLER RIDGE
CIRCUIT DESIGNATION PROTECTION T1
PHASE OR LOCATION IN PANEL T1-LV
STYLE NO. _____ FUNCTION 51-T1-LV
P.T. RATIO _____
INSTANTANEOUS N/A AMPS.
INSTAN. OPERATIONS INDICATOR _____
CURVE VERY INVERSE
MFG. GEC TYPE EDG 13 AF 2162 AG
C.T. RATIO _____
TAP RANGE 2.5 - 10
TIME OPERATIONS INDICATOR SHUNT. AMPS.
SER. NO. _____

CONDITION	SETTINGS			RELAY TESTS									
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS	2 x TAP: A. LIMITS SEC. CYCLES	5 x TAP: A. LIMITS SEC. CYCLES	10 TAP: A. LIMITS SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS	TARGET OPER. AMPS DC OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	10	0.2	N/A	10.3-N.S	3.2	0.53	0.3	—					
A Ø AS FOUND				10.4	3.07	0.51	0.31	-	OK		INFT	Oct 91	FLN
AS LEFT				10.4	3.07	0.51	0.31	-	OK				
B Ø AS FOUND													
AS LEFT													
C Ø AS FOUND													
AS LEFT													
N/G SPECIFICATIONS													
AS FOUND													
AS LEFT													

REMARKS: SERIAL No. 088468N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION B.C. RAIL - TUMBLER RIDGE
RELAY VERY INVERSE
MFG. G.E.C. TYPE CDG23AF611BX6
C.T. RATIO
TAP RANGE 2.5 - 10 / 0.5 - 2
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION PROTECTION TR
PHASE OR LOCATION IN PANEL TR
STYLE NO. FUNCTION 50/51 - TR
P.T. RATIO
INSTANTANEOUS 20 - 80 / 2 - 8
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION	SETTINGS: TAP AMPS	SETTINGS: TIME DIAL	SETTINGS: INST. AMPS	RELAY TESTS: PICK-UP AMPS LIMITS ----	2 x TAP: A. LIMITS ---- SEC. ~~CYCLES~~	5 x TAP: A. LIMITS ---- SEC. CYCLES	10x TAP: A. LIMITS ---- SEC. ~~CYCLES~~	INST. AMPS	TARGET OPER. AMPS DC ICS	TARGET OPER. AMPS DC OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	7.5	0.4	25	7.1 - 7.95	6.7	1.04	0.60						
A@ AS FOUND				7.8	6.7	1.04	0.60	PU 7					
AS LEFT				7.9	6.7	1.04	0.60	24.7	OK		10000+	OUT 83	I-LN
B@ AS FOUND				7.9	6.02	0.99	0.59						
AS LEFT				7.9	6.02	0.99	0.59	24.7	OK		1000+	OUT 93	I-LN
C@ AS FOUND													
AS LEFT													
N@ TYPE CDG23AF611BX6													
SPECIFICATIONS	1.2	0.1	5	1.23 - 1.26	1.6	0.26	0.15						
AS FOUND				1.25	1.52	0.27	0.17						
AS LEFT				1.25	1.52	0.27	0.17	5.0	OK.		1000+	OUT 89	I-LN

REMARKS: SERIAL No.- A@ 088463N ; B@ 088461N ; NEUTRAL 088464N

TEST REPORT
UNDER/OVER VOLTAGE RELAY

CIRCUIT LOCATION B.C. RAIL - TUMBLER RIDGE
RELAY
MFG. G.E.C. TYPE VDG 13AF2122A6
C.T. RATIO
TAP RANGE 55 - 99
TIME OPERATIONS INDICATOR SHUNT AMPS.
IL NO.

CIRCUIT DESIGNATION
PHASE OR LOCATION IN PANEL
STYLE NO. FUNCTION 27 IIV
P.T. RATIO
INSTANTANEOUS N/A.
INSTAN. OPERATIONS INDICATOR AMPS.

CONDITION		SETTINGS			RELAY TESTS									
		TAP VOLTS	TIME DIAL	INST. VOLTS	PICK-UP AMPS LIMITS ---	120 V → 0V ~~x TAP~~ LIMITS ---- SEC. CYCLES	120 V → 85% ~~x TAP~~ LIMITS ---- SEC. CYCLES	x TAP LIMITS ---- SEC. CYCLES	INST. VOLTS	TARGET OPER. AMPS DC ICS OI	500V INSUL TEST MEGOHMS	DATE	INT.
	SPECIFICATIONS	99	1.0	-	103.5	5.1	17.3	-	-	SHUNT			
A∅	AS FOUND				99	4.82	15.7	-	-	OK			
	AS LEFT				104	5.0	16.9			OK	1500+	OCT 83	FLN
B∅	AS FOUND												
	AS LEFT												
C∅	AS FOUND												
	AS LEFT												

REMARKS: SERIAL No. 088509N

TEST REPORT
OVERCURRENT RELAY

CIRCUIT LOCATION B.C. RAIL - TUMBLER RIDGE
RELAY Bus Differential
MFG. G.E.C. TYPE CAG 14AF36A
C.T. RATIO
TAP RANGE 1 - 4
TIME OPERATIONS INDICATOR Shunt AMPS.
IL NO.

CIRCUIT DESIGNATION Protection L1
PHASE OR LOCATION IN PANEL 50KV Bus
STYLE NO. FUNCTION 87B
P.T. RATIO
INSTANTANEOUS AMPS.
INSTAN. OPERATIONS INDICATOR

CONDITION	SETTINGS			RELAY TESTS								
	TAP AMPS	TIME DIAL	INST. AMPS	PICK-UP AMPS LIMITS ----	2 x TAP: A. LIMITS ---- SEC. CYCLES	x TAP: A. LIMITS ---- SEC. CYCLES	x TAP: A. LIMITS ---- SEC. CYCLES	INST. AMPS	TARGET OPER. AMPS DC ICS OI	500V INSUL TEST MEGOHMS	DATE	INT.
SPECIFICATIONS	3.5		—					—	Shunt			
A Ø AS FOUND			—	3.4	.0137			—	OK		Oct 93	FHH
AS LEFT			—	3.4	.0137							
B Ø AS FOUND												
AS LEFT												
C Ø AS FOUND												
AS LEFT												
N/G SPECIFICATIONS												
AS FOUND												
AS LEFT												

REMARKS: SERIAL No. 0028337

B.C. RAIL - TUMBLER RIDGE

21 - L1
G E C

YTG14

SERIAL 002412P

Settings

K_1 K_2 K_3 - Adjusted as required
K_4 - 1
K_5 - 8
K_6 - 1 (75°)
K_8 - 1

Z_1 Ø 75°
Z_2 Ø 75°

Z_1 Time - 30 MS
Z_2 Time - + 200 MS
Z_{3F} Time - + 700 MS
Z_{3R} Time - + 700 MS

TESTS AND ADJUSTMENTS

Angle of Max. Torque (Ø) E Leads I

Z_1 = (Checked at 15 Volt & 4 Amp = 3.75 OHMS) P.U. Between
127° to 31° = 79°
Adjusted to 123° to 26° = 74.5°

Z_2 = (Checked at 45 Volt & 4 Amp = 11.25 OHMS) P.U. Between
116° to 38° = 77°

Z_3 = (Checked at 70 Volt & 4 Amp = 17.5 OHMS) P.U. Between
83° to 67° = 75°

21-L1

ZONES - All checked from a starting voltage of 100 Volt and current of 2 Amp and shifting to the valves shown.

Z_{3R} - Required 0.9 - Should be 3.6 Volt and 4 Amp
Set to 3.79 Volt and 4 Amp = 0.95 OHMS

Z_{3F} - Required 18.5 - Should be 74 Volt and 4 Amp
Set to 74.16 Volt and 4 Amp = 18.54 OHMS

Z_2 - Required 13.9 - Should be 55.6 Volt and 4 Amp
Set to 55.57 Volt and 4 Amp = 13.89 OHMS

Z_1 - Required 9.1 - Should be 36.4 Volt and 4 Amp
Set to 32.36 Volt and 4 Amp = 8.09 OHMS - This is limit of adjustment.

TIME - From 100 Volt and 2 Amp to the valves shown.

Z_{3R} - 2 Volt and 4 Amp (0.5 OHMS) = 728.1 MS
Z_{3F} - 64 Volt and 4 Amp (16 OHMS) = 720.3 MS
Z_2 - 44 Volt and 4 Amp (11 OHMS) = 214.1 MS
Z_1 - 16 Volt and 4 Amp (4 OHMS) = 13.8 MS
Z_1 - 0 Volt and 4 Amp (0 OHMS) = 11.5 MS

- From Zero Volt and Zero Amp

Z_1 - 5 Volt and 4 Amp (1.25 OHMS) = Less than 0.0 MS

NOTE:

Operation also checked on 75 Volt D.C. Supply.

No Operation with reverse voltage except as noted under Z_{3R}.

OCTOBER, 1983 - FLH

OMEGA TECHNICAL SERVICES LTD.

B.C. RAIL - TUMBLER RIDGE

21 - L2
GEC

YTG14

SERIAL 002413P

Settings

K_1 K_2 K_3 - Adjusted as required
K_4 - 1
K_5 - 8
K_6 - (75°)
K_8 - 1

Z_1 Ø 75°
Z_2 Ø 75°

Z_1 Time - 30 MS
Z_2 Time - + 200 MS
Z_{3F} Time - + 700 MS
Z_{3R} Time - + 700 MS

TESTS AND ADJUSTMENTS

Angle of Max. Torque (Ø) E Leads I

Z_1 = (Checked at 15 Volt & 4 Amp = 3.75 OHMS) P.U. Between 121° to 29° = 75°

Z_2 = (Checked at 45 Volt & 4 Amp = 11.25 OHMS) P.U. Between 99° to 53° = 76°

Z_3 = (Checked at 70 Volt & 4 Amp = 17.5 OHMS) P.U. Between 91° to 62° = 76.5°

21-L_2

ZONES - All checked from a starting voltage of 100 Volt and current of 2 Amp and shifting to the valves shown.

Z_{3R} - Required 0.9 - Should be 3.6 Volt and 4 Amp
Set to 3.52 Volt and 4 Amp = 0.88 OHMS

Z_{3F} - Required 18.5 - Should be 74 Volt and 4 Amp
Set to 73.88 Volt and 4 Amp = 18.47 OHMS

Z_2 - Required 13.9 - Should be 55.6 Volt and 4 Amp
Set to 55.43 Volt and 4 Amp = 13.86 OHMS

Z_1 - Required 9.1 - Should be 36.4 Volt and 4 Amp
Set to 32.22 Volt and 4 Amp = 8.06 OHMS - This is limit of adjustment.

TIME - From 100 Volt and 2 Amp to the valves shown.

Z_{3R} - 2 Volt and 4 Amp (0.5 OHMS) = 783 MS
Z_{3F} - 64 Volt and 4 Amp (16 OHMS) = 710.8 MS
Z_2 - 44 Volt and 4 Amp (11 OHMS) = 216.9 MS
Z_1 - 16 Volt and 4 Amp (4 OHMS) = 12.6 MS
Z_1 - 0 Volt and 4 Amp (0 OHMS) = 12.2 MS

- From Zero Volt and Zero Amp

Z_1 - 5 Volt and 4 Amp (1.25 OHMS) = Less than 0.0 MS

NOTE:

Operation also checked on 75 Volt D.C. Supply.

No Operation with reverse voltage except as noted under Z_{3R}.

OCTOBER, 1983 - FLH

OMEGA TECHNICAL SERVICES LTD.

B.C. RAIL - TUMBLER RIDGE

60A/T-C1

G E C DTCP 11 PF2007A SERIAL 090509N

Range 0 - 3

Compensation 0 -7

Compensation 0

Settings
- Tap 0.5
- Alarm 3% or Tap
- Trip 6% of Tap

Operation

Winding #1	At 1.00 Amp
Winding #2	At 1.033 - Alarms
Winding #2	At 1.066 Amp - Trips
Winding #2	At 1.00 Amp
Winding #1	At 1.035 Amp - Alarms
Winding #1	At 1.073 Amp - Trips

TMP-C1

G E C VTT 24BF5206BA SERIAL 088484N

Settings
- Alarm 2.2 Sec
- Trip 2.2 Sec

Measured
- Alarm 2.22 Sec
- Trip 2.22 Sec

OCTOBER, 1983 FLH

OMEGA TECHNICAL SERVICES LTD.

B.C. RAIL - TUMBLER RIDGE

2 - 50 BF - L_1

G E C VTT 14NG5206BA SERIAL 088489N

Setting - 2.2 Sec
Measured - 2.23 Sec

2 - 50 BF - L_2

G E C VTT 14NG5206BA SERIAL 088488N

Setting - 2.20 Sec
Measured - 2.24 Sec

2 - 50 BF - C_1

G E C VTT 14NG5206BA SERIAL 088490N

Setting - 2.20 Sec
Measured - 2.23 Sec

OCTOBER, 1983 FLH

OMEGA TECHNICAL SERVICES LTD.

APPENDIX D

SERIES CAPACITOR STATION TEST RESULTS

NOKIA ENGINEERING

0783M I Berg/as 10.11.1983 1

TEST REPORT

BRITISH COLUMBIA RAILWAY
SERIES CAPACITOR STATION - KM 67 TUMBLER RIDGE
BRANCH LINE

Testing and commissioning was made according to Houle Electric Ltd letter 17 Oct. 1983 File: 4542.

Because of the 50 kV line was not yet supplied the needed AC-power was made by a small 3000 W generator.

This caused some problems during the tests.

The voltage was not stable causing fluctuations in the readings of the meter. So all the readings are somewhat approximately.

The frequency of the generator was too low so it was not possible to measure the capacitance of the capacitors.

The following tests were carried out at site on the 2nd and 3rd November.

Metering

Current transformer 1 800/5 A/10 mA

Input terminals 30, 31
Output terminals 68, 69

Input (A)	1.36	2.8	4.02	5.06	6.00
Signal reading (A)	200	400	600	800	1000
Output (mA)	2.71	5.60	8.09	10.20	12.06

VT 1 outgoing 50 kV/120 V/10 mA

Input terminals 22, 23
Output terminals 66, 67

Input (V)	22.8	28.0	73.4	99.2	115.6
Signal reading (kV)	10	20	40	40	47
Output (mA)	1.92	3.96	605	8.20	9.60

VT 2 incoming

Input terminals 24, 25
Output terminals 70, 71

Input (V)	21.4	46.6	72.8	96.2	115.2
Signal reading (kV)	10	20	30	40	47
Output (mA)	1.93	4.20	6.12	8.02	9.58

VT 1 should be incoming voltage and VT 2 should be outgoing voltage. The terminal numbers have been changed in revised drawing E1-681b.

Control

The correct operation of the switchgear was tested from Control Panel and from Remote Terminal Unit contacts. During control tests it was tested that operation was prevented from non selected location.

The electrical interlocking was tested to prevent faulty operation.

Protection

Spark gap
Printed circuit SG01A 1/83
Spark gap relay picks up at 4.5 A

Auto reset on
First operation
BPCB closed and after preset delay 5-20 s the bank was reinserted

Second operation within 30 min
- BPCB closed
- MOD BY-PASS closed
- BPCB opened

Auto reset off
First operation
BPCB closed and stayed closed unless reinserted manually

Second operation
- BPCB closed
- MOD BY-PASS closed
- MOD CAP opened

The operation of printed circuit SG01A 2/83 was the same.

Unbalance

Printed circuit 1UR01A	1/83
Alarm pick-up sensitivity	0.29 A
Alarm pick-up delay	0.87 s
Trip pick-up sensitivity	0.57 A
Trip pick-up delay	1.30 s

Printed circuit 1UR01A	2/83
Alarm pick-up sensitivity	0.29 A
Alarm pick-up delay	0.87 s
Trip pick-up sensitivity	0.55 A
Trip pick-up sensitivity	0.70 s

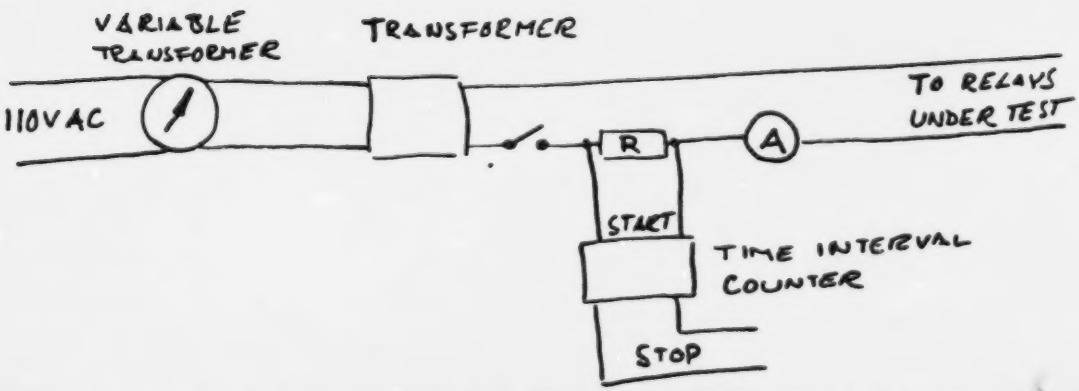
Overload

Printed circuit 1TR05A	1/83
Overload trip	7.3 A, 5 min
Fast resert	53 s
Printed circuit	2/83
Overload trip	7.3 A, 9 min
Fast resert	50 s .
Printed circuit 1SV02A	1/83
Sustained overvoltage trip	
Sust overvoltage I	7.6 A, 1.01 s
Sust overvoltage II	9.4 A, 0.21 s
Printed circuit 1SV02A	2/83
Sustained overvoltage trip	
Sust overvoltage I	7.6 A, 1.00 s
Sust overvoltage II	9.5 A, 0.20 s

During protection tests all the remote alarms were checked.

The current consumption was measured to be 94.3 mA.

Current insection test



Service
Westinghouse Canada Inc.

2235 Nicholson Street
Prince George British Columbia
V2N 1V9
Telephone (604) 562-5571

November 28,1983

Houle Electric Ltd.
3635 Opie Crescent
Prince George B.C.
V2N 1B9

Attention:Frank Houle

Re: Your P.O. #4542
Our Job S94-8341

Please find attached our test results on the BCR capacitor station. Due to bad weather conditions, we could not perform a Doble test on the capacitor bank. The tests performed on all other equipment indicated that the equipment is in good order.

We found a wrong connection from CT-3 and CT-4 which was due to print error which has the CT designation on equipment lay-out print reversed. Also CT-3 ratio of 10/5 indicated on single line diagram is wrong and should be 10/1. In checking the operation of the relay protection, we question how the sustained overvoltage relay operates. The only connection to this relay is from a CT and as expected gave a trip when overcurrent was applied but indicated sustained overvoltage trip. No overcurrent trip indication was obtained. There is provision for a connection from VT-2 voltage transformer but there is no wiring in relay panel. It was also noted that when the DC supply to protective relay panel was removed and re-applied, the Logic would lock up and have to be cleared by pulling cards and re-inserting.

(corrected → sustained overvoltage relay operates
connected → there is no wiring in relay panel
corrected → by pulling cards and re-inserting.)

We are glad to have been of service to you and if you have any questions or require further assitance, please call.

Yours truly

Don Munk, C.E.T.
Field Service Representative
Prince George Branch
Industry Services Division

DM/jf
encl

November 28,1983

Your P.O # 4542
Our Job S94-8341

Ratio Test of CT'S

CT-1	800/5 Ratio applied 80 Amps primary read 0.51 Amps secondary
CT-2	800/5 Ratio applied 80 Amps primary read 0.50 Amps secondary
CT-3	10/1 Ratio applied 50 Amps primary read 5 Amps secondary
CT-4	800/5 Ratio applied 80 Amps primary read 0.50 Amps secondary

Secondary current was read at connection to relay panel.

Circuit Breaker Test

Contact Resistance Closed

A Phase	290 micro ohms at $-3^{o}C$
B Phase	325 micro ohms at $-3^{o}C$

Open Meggar

A Phase
B Phase

Doble test at 10 kV $-3^{o}C$ 65% humidity

A Phase	21 x 10 u Amp. =	.210 milliamperes
	71 x .01 u Amp.=	.71 Watts
		34 % Power factor
B Phase	16 x 10 u Amp. =	.160 milliamperes
	34 x .01 u Amp.=	.34 Watts
		21 % Power factor

November 28,1983

Your P.O. # 4542
Our Job S94-8341

Protective Relay Test

Input from CT-2 lead 32-33
applied 7.5 Amps. tripped CB on sustained undervoltage

Input from CT-3 lead 34-35
applied .65 Amps. tripped CB on unbalance

Input from CT-4 lead 36-37
applied .45 Amps. tripped CB and operated disconnect switches on spark gap

Input from VT-2 lead 26-27
no circuit connected

NOKIA ENGINEERING

0998M/BOWI/mj

19.3.1984

ROUTINE TEST REPORT

PROTECTION AND CONTROL CUBICLE PRC-11

BRITISH COLUMBIA RAILWAY
SERIES CAPACITOR STATION AT KM 67
TUMBLER RIDGE BRANCH LINE

The routine tests carried out on the control and protection cubicle covers tests on individual printed circuit boards as well as on the complete assembled unit.

The purpose of the tests on the individual units is to check that each unit is assembled correctly with specified operating sensitivity, time and adjustment range. The results of these tests are recorded on the enclosed production records.

The purpose of the tests on the assembled cubicle is to check the correct assembly of the individual components into a complete system. These tests follow an individual test program made for each separate project. A translation of this program and the test results are attached.

BRITISH COLUMBIA RAILWAY
APR 12 1984
OFFICE OF

ROUTINE TEST PROGRAM FOR PROTECTION AND CONTROL CUBICLE PRC-11

Visual inspection

Check that the assembly is in accordance with our general quality standards and carried out according to relevant drawings.

Check that the wiring is according to instructions.

Electrical tests

Power supply

Check the operation of the 125/24V DC/DC converter, the regulated power supply 3PRO8A and the distribution of the DC supply.

Metering

Check the operation and accuracy of the indication instruments and measuring transducers by injecting a current or voltage as appropriate to corresponding terminal blocks. Compare the readings to the specified accurancy.

Manual control

Check the operation of local and remote manual controls. Ensure that only safe operation sequences are possible, i.e.

- close/open of BPCB always possible
- close/open of MOD BY-PASS only when BPCB and MOD CAP are closed
- close/open of MOD CAP only when BPCB and MOD BY-PASS are closed
- local/remote control possible only as selected

Testing of remote manual control is simulated from the corresponding terminal blocks.

Protection

Check the operation of each protection feature by injecting a current or voltage as appropriate to corresponding terminal blocks of the relay cubicle. Monitor the operating sequence of the control commands, the local and remote alarm annuniation.

TEST REPORT

BRITISH COLUMBIA RAILWAY
SERIES CAPACITOR STATION - KM 67 TUMBLER RIDGE
BRANCH LINE

Testing and commissioning was made according to Houle Electric Ltd letter 17 Oct. 1983 File: 4542.

Because of the 50 kV line was not yet supplied the needed AC-power was made by a small 3000 W generator.

This caused some problems during the tests.

The voltage was not stable causing fluctuations in the readings of the meter. So all the readings are somewhat approximately.

The frequency of the generator was too low so it was not possible to measure the capacitance of the capacitors.

The following tests were carried out at site on the 2nd and 3rd November.

Metering

Current transformer 1 800/5 A/10 mA

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Output terminals 68, 69

Input (A)	1.36	2.8	4.02	5.06	6.00
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VT 1 outgoing 50 kV/120 V/10 mA

Input terminals 22, 23
Output terminals 66, 67

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VT 2 incoming

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Output terminals 70, 71

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Output (mA)	1.93	4.20	6.12	8.02	9.58

VT 1 should be incoming voltage and VT 2 should be outgoing voltage. The terminal numbers have been changed in revised drawing E1-681b.

Control

The correct operation of the switchgear was tested from Control Panel and from Remote Terminal Unit contacts. During control tests it was tested that operation was prevented from non selected location.

The electrical interlocking was tested to prevent faulty operation.

Protection

Spark gap
Printed circuit SG01A 1/83
Spark gap relay picks up at 4.5 A

Auto reset on
First operation
BPCB closed and after preset delay 5-20 s the bank was reinserted

Second operation within 30 min
- BPCB closed
- MOD BY-PASS closed
- BPCB opened

Auto reset off
First operation
BPCB closed and stayed closed unless reinserted manually

Second operation
- BPCB closed
- MOD BY-PASS closed
- MOD CAP opened

The operation of printed circuit SG01A 2/83 was the same.

Unbalance

Printed circuit 1UR01A	1/83
Alarm pick-up sensitivity	0.29 A
Alarm pick-up delay	0.87 s
Trip pick-up sensitivity	0.57 A
Trip pick-up delay	1.30 s

Printed circuit 1UR01A	2/83
Alarm pick-up sensitivity	0.29 A
Alarm pick-up delay	0.87 s
Trip pick-up sensitivity	0.55 A
Trip pick-up sensitivity	0.70 s

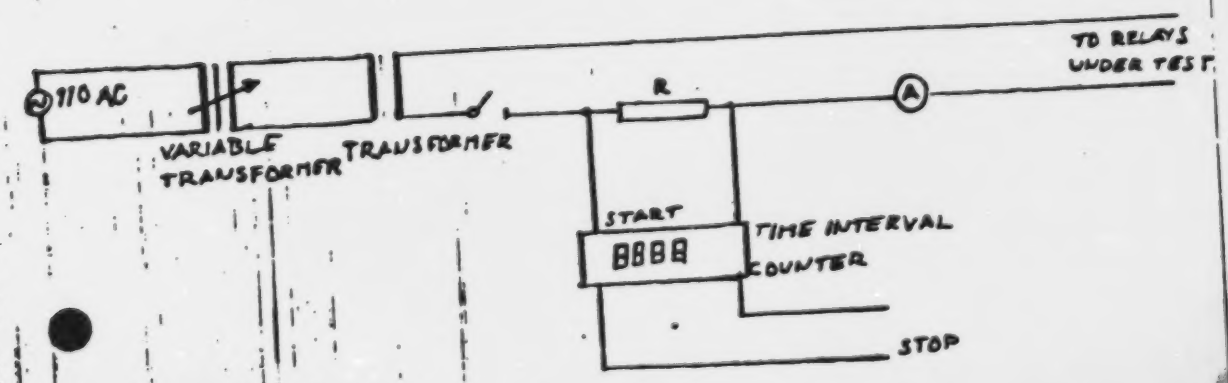
Overload

Printed circuit 1TR05A	1/83
Overload trip	7.3 A, 5 min
Fast resert	53 s
Printed circuit	2/83
Overload trip	7.3 A, 9 min
Fast resert	50 s
Printed circuit 1SV02A	1/83
Sustained overvoltage trip	
Sust overvoltage I	7.6 A, 1.01 s
Sust overvoltage II	9.4 A, 0.21 s
Printed circuit 1SV02A	2/83
Sustained overvoltage trip	
Sust overvoltage I	7.6 A, 1.00 s
Sust overvoltage II	9.5 A, 0.20 s

During protection tests all the remote alarms were checked.

The current consumption was measured to be 94.3 mA.

Current insection test



ACCEPTANCE TEST REPORT

B.C. Rail, Thumbler Ridge Branch Line
Series Capacitor Station 13.5 MVAr 50 kV
Protection Tests, High Voltage Energization
3rd February, 1984

John Popoff, B.C. Rail
William Hall, Houle Electric
Pekka Ritamäki, Nokia Corporation

1
General

The purpose of the acceptance test was to ensure right operation of the capacitor bank and allow B.C. Rail to use the bank in normal service.

2
The Protection Test

2.A.1
Spark Gap Test

The function of the spark gap relay is to close breaker immediately after spark gap operation and open breaker after line voltage is restored and reinsertion delay has elapsed.

2.A.2
Test Sequence

1A current was connected to terminals at the relay cabinet for approximately half a second. Line voltage input (120 V) was then removed. After appr. 5 minutes later the line voltage was connected on again.

2.A.3
Test Result

After spark gap current was connected the bypass breaker closed immediately. When the line voltage was connected on again the breaker operated after 17 second reinsertion delay. Spark gap indication remains on.

During second test the sustained spark gap indication light came up and the breaker closed. It did not open after the line voltage was restored. The test sequence was according to specifications.

2.B.1
Sustained Overvoltage Test

Function of the sustained overvoltage relay is to close bypass breaker if overvoltage is more than $1.6 \times U_N$ 1 second or $2.0 \times U_N$ 0.2 second.

2.B.2
Test Sequence

The test current was connected to the line current input terminals at the relay cabinet.

2.B.3
Test Results

Sustained overvoltage stage I-relay operated at 7.9 A (error 1% to calculated 8 A value).

Sustained overvoltage stage II relay operated at 10 A (error 0%). In both cases the breaker closed as specified. The sustained overvoltage lamp indicated the operation until reset button was pressed.

2.C.1
Overload Relay

The purpose of the overload relay is to close breaker if the time/current characteristics is exceeded.

2.C.2
Test Sequence

A 7.5 A test current was applied to the line current input at the relay cabinet.

2.C.3
Test Result

The breaker operated at 9 min. and 20 seconds after the current was applied (10 min. specified). The thermal relay dropped out after 27 minutes cooling time (30 min. specified). The operation of the relay is according to specifications.

2.D.1
Unbalance Relay

The purpose of the unbalance relay is to give an alarm indication if unbalance current is more than 0.3 A for 1 second and close the breaker if the current is more than 0.6 A for 1 second.

2.D.2
Test Sequence

The test current was applied to unbalance current terminals at the relay cabinet.

2.D.3
Test Result

The unbalance alarm operated at 0.305 A. The breaker closed at 0.58 A (3% error) and the unbalance trip light came up. The relay worked according to the specifications.

3
Bypass Breaker and MOD Interlock

3.A.1

The purpose of the interlock is to prevent unwanted operation of breaker and MODs.

3.A.2
Test Sequence

Possible operations:

- Close and open for BPCB always
- Open or close bypass MOD when BPCB is closed and isolation MOD is closed
- Open or close isolation MOD only when bypass MOD is closed and bypass circuit breaker is closed

The interlock of operations is made internally by using relay logic and externally using auxiliary switches of the breaker and MODs.

3.A.3
Test Result — All possible operations operated. All other combinations were prevented.

4
High Voltage Energization

4.A.1 — The purpose of high voltage energization was to check that all equipment are capable to stand high voltage at actual conditions.

4.A.2
Test Sequence — The capacitor bank was bypassed by the BPCB and MOD. The grounding blades were openend and the isolation MOD was closed.

4.A.3 — The line was energized.

4.A.4 — The system voltage measured from relay cabinet terminals was 122.6 V x 50000/120 = 51083 V.

The incoming voltmeter reads 50.95 kV and outgoing voltmeter reads 51.3 kV. The 0.5% error was corrected. The spark gap relay did not get voltage input at all. After two cable wiring errors were corrected, the spark gap relay line voltage-indication worked correctly. The positions of the bypass MOD auxiliary switches were adjusted.

4.A.5 — The bank was left energized for 10 h. There were no alarms after 10 h test time.

5
The Results of Acceptance Tests

All the tests required by B.C. Rail Engineer were fulfilled satisfactorily. The B.C. Rail is allowed to use capacitor bank freely after these acceptance tests.

9th February 1984

Pekka Ritamäki
Design Manager

NOKIA CORPORATION
Engineering

NOKIA
Engineering
2689T

I Berg/as 9.3.1984

BC-RAIL COMMISSIONING TEST PROGRAM

System conditions

Rated voltage, single phase	50 kV
Eight operating voltage	55 kV
Rated current	800 A
Highest continuous current	
Capacitor bank rated current	917 A

Metering

Voltage meters, two	
scale	0...60 kV, 250°
PT ratio	50 kV/120/120 V
Accuracy	1%
Current meter, one	
scale	0...1000 A, 250°
CT ratio	800/5 A
Accuracy	1%
Voltage transducers, two	
input	0...120 V
output	0...10 mA
signal range	0...120%
Current transducers, one	
input	0...5 A
output	0...10 mA
signal range	0...120 %

TELEX: 124276 CABNO SF
TELEGRAMS:

Control	Manual	
	Remote/local, selected feature indicated	
	Note: During manual control tests the remote/local selection feature is tested to prevent operation from non selected location.	
	Lamp test feature	
	Switchgear control/indication	
	Open BPCB	
	Close BPCB	
	Open & close BPCB = close BPCB	
	Open Mod Cap, if BPCB & MOD BY-PASS closed	
	Close Mod Cap, if BPCB & MOD BY-PASS closed	
	Open Mod By-Pass, if BPCB & Mod Cap closed	
	Close Mod By-Pass, if BPCB & Mod Cap closed	
	Note: Switchgear control/indication tests to be carried out for local and remote control.	
Protection	Spark gap	
	Relay pick-up	@1000A/800/5=6.25A
	Initiate temporary by-pass	
	Reinsert delay adjust	5-20 s, if $I=I_N$
	Insert pulse	1.0 s
	Repeated fault timer	approx. 30 min
	Permanent by-pass if repeated fault	
	Operation stored in memory	
	Unbalance	
	Alarm pick-up sensitive	@3A/50/5=0.3A
	Alarm pick-up delay	@6A/50/5=0.6A, 1s
	Trip pick-up sensitivity	@6A/50/5=0.6A
	Trip pick-up delay	@12A/50/5=1.2A, 1s
	Operation stored in memory	

Overload	
Trip pick-up sensitivity	@ 7.5 A, 10 min.
Operation indicated and stored	
Reset time, fast reset	30 s
Sustained overvoltage	
Rated current pick-up sensitivity	@ 800/800/5 = 5 A
Sustained overvoltage trip operation	
stage I pick-up sensitivity/delay	
stage II pick-up sensitivity/delay	
Operation stored in memory	

Recommended test equipment

Variable transformer 120 V 8 A
General purpose instrument
- current range 10 A
Limiting resistor 5 ohm/500 W

NOKIA
CAPACITOR DIVISION

ROUTINE TEST REPORT

65.70/6.1.452 7.07.1983

EN-23125-2625-2656060

Nokia Engineerin/B.C.Rail

Nokia
Acknowl. No. 138100

Product Quantity

Type of reactor 1-phase damping reactor
XUVL 4.5mH/917A
No. 832738

Dambing resistor 9Ω /0.41 MJ

Specification

IEC Publication 289

The goods have been inspected and tested in accordance with the tests of specifications, and they were found to meet all requirements stated.

The tests were carried out in Tampere at Nokia Corporation Capacitors 3.7.1983.

The following tests have been performed on reactor:

1. Voltage test:
   The voltage test is carried out as capacitor disharge.
   The capacitor bank is charged on DC voltage and discharged to reactors.

2. Measurement of impedance IEC 289 10.3
   The inductance of the reactor is measured by the Tettex bridge type 2801 and normal mutual inductance Tettex type 3480.

3. Measurement of winding resistance IEC 289 10.2
   The winding resistance is measured with Kelvin bridge L&N type 4287.

Routine test report is enclosed.

Nokia Corporation
Capacitor Division
Laboratory

NOKIA

Kondensaattorit Capacitors

ROUTINE TEST REPORT OF REACTORS

Customer	NOKIA ENGINEERING/B.C.H	Rep. 6570/6.1.452	Side 1
Order acknowl. no	38100	Meas. HH.	Σ 5 1
Work no	G0432.	Contr. HK	7.7 1985
		Copy HH. JS. JH	Specif. IEC 289

Type of reactor: XUVL 4,5 mH / 917 A

Reactor no	Meas values at +21 °C				Market values		Voltage test 67 kV	
	Imped. Z/Ω	Induct. L/m H	Resist R/m Ω	Losses P/kW	Imped. Z/Ω	Induct L/m H		
83/2738		5.10	10.41			5.1	OK	
	DAMPING RESISTOR:							
	MEAS. VALUE		9Ω			+21 °C		

PRODUCTION RECORD

Unit	Type
Relay Cabinet	PRC-11

Drawings

S	E1-681, E2-684	Front plate:	E3-687
PL	E4-683, E4-685	Label:	E4-1214 E4-1480 E4-1481
A	E3-680		

Manufacturing details

Quantity: 1 Serial no: 01

Toti: BC Rail 106922

Date: 6.9.83 OK

Remarks

After installation the spark gap relay 1SG01A was replaced by the spark gap relay 3SG02A. The operation with the new relay was tested at site during commissioning. 15/2-84 OK

Routine tests

Serial no: 01

Visual inspection: ok

Electrical tests:

Power supply	ok
Metering	OK
Manual control	ok
Protection	OK

Approved: 21/9-83

PRODUCTION RECORD

Unit	Type
Spark Gap Relay	3SG02A

Drawings

S	E3-1440	Front plate:	E4-1216
PL	E4-1441	Label:	E4-1483
A	E4-1442		

Manufacturing details

Quantity: 2

Serial no: 01-02

Toti: BC Rail 106922

Date: 7.12.-83 GR

Remarks

Routine tests

Serial no: 01 02

Visual inspection: OK

Electrical tests:

- Calibration according to instructions	OK	OK
- Operation		
single spark gap flashover	OK	OK
sustained spark gap current	OK	OK
repeated spark gap flashover	OK	OK
line de-energized	OK	OK
line de-energized after spark gap flashover	OK	OK
reinsert at line current > 1 pu	OK	OK

Approved: 13/12-83

PRODUCTION RECORD

Unit	Type
Unbalance Relay	1UR01A

Drawings

S	E4-701	Front plate:	E4-1101
PL	E4-703	Label:	E4-1482/5 E4-1484
A	E4-702		

Manufacturing details

Quantity: 2
Serial no: 01-02
Toti: BC Rail 106922
Date: 29.8-83 OR

Remarks

Routine tests

	Serial no: 01	02
Visual inspection:	OK	
Electrical tests:		
- Calibration according to instructions	OK	OK
- Operation	OK	OK
alarm	OK	OK
trip	OK	OK

Approved: 9/9-83
RS

PRODUCTION RECORD

Unit	Thermal Overload Relay	Type	1TR05A

Drawings

S	E3-704	Front plate:	E4-016
PL	E4-706	Label:	E4-1482/2 E4-1484
A	E4-705		

Manufacturing details

Quantity: 2

Serial no: 01-02

Toti: BC Rail 106922

Date: 30.8-83 OR

Remarks

Routine tests

Serial no: 01 02

Visual inspection: OK

Electrical tests:

- Calibration according to instructions	OK	OK
- TP4 pulse duration versus input voltage according to specification	OK	OK
- Relay operation at > 1.5 pu	OK	OK

Approved: 9/9-83

RS

PRODUCTION RECORD

Unit	Type
Sustained Overvoltage Relay	16V02A

Drawings

S	E3-707	Front plate:	E4-1100
PL	E4-709	Label:	E4-1482/3 E4-1484
A	E4-708		

Manufacturing details

Quantity: 2
Serial no: 01-02
Toti: BC Rail 106922
Date: 31 8-83 OK

Remarks

Routine tests

	Serial no: 01	02
Visual inspection: OK		
Electrical tests:		
- Calibration according to instructions	OK	OK
- Operation	OK	OK
rated line current	OK	OK
sust. overv. stage I	OK	OK
sust. overv. stage II	OK	OK

Approved: 8/9-83
RS

PRODUCTION RECORD

Unit	Monitor Relay Unit	Type	3MR02B

Drawings

S	E4-713	Front plate:	E4-020
PL	E4-715	Label:	E4-1482/1 E4-1484
A	E4-714		

Manufacturing details

Quantity: 2

Serial no: 01-02

Toti: BC Rail 106922

Date: 31.8-83 OK

Remarks

Routine tests

	Serial no: 01	02
Visual inspection: OK		
Electrical tests:		
To be tested during the protection tests of the complete cabinet	OK	OK

Approved: 9/9-83

PRODUCTION RECORD

Unit	Type
Diode Board	

Drawings

S	E4-691	Front plate:	-
PL	E4-693	Label:	-
A	E4-692		

Manufacturing details

Quantity: 2

Serial no: 01-02

Toti: BC Rail 106922

Date: 1.9-83 OE

Remarks

Routine tests

	Serial no: 01	02
Visual inspection:	OK	
Electrical tests:		
To be tested in the complete assembly	OK	OK

Approved: 9/9-83

RS

PRODUCTION RECORD

Unit	Type
Connector Plate 2	

Drawings

S	E4-696	Front plate: -
PL	E4-697	Label: -
A	E4-696	

Manufacturing details

Quantity: 2

Serial no: 01-02

Toti: BC Rail 106922

Date: 1.9-83 OTU

Remarks

Routine tests

	Serial no: 01	02
Visual inspection:	OK	
Electrical tests:		
To be tested with the complete assembly	OK	OK

Approved: 9/9 -83

RS

PRODUCTION RECORD

Unit	Type
Connector Plate 1	

Drawings

S	E4-694	Front plate: -
Pl	E4-695	Label: -
A	E4-694	

Manufacturing details

Quantity: 2

Serial no: 01-02

Toti: BC Rail 106922

Date: 2.9-83 OR

Remarks

Routine tests

Serial no: 01 02

Visual inspection: OK

Electrical tests:

Voltage limiters OK OK

Approved: 9/9-85 RS

PRODUCTION RECORD

Unit	Type
Reset Unit	3RS01A

Drawings

S	E4-716
PL	E4-718
A	E4-717

Front plate: 4E1227

Label: E4-1481, E4-1484

Manufacturing details

Quantity: 2

Serial no: 01-02

Toti: BC Rail 106922

Date: 29-83 OE

Remarks

Routine tests

	Serial no: 01	02
Visual inspection:	OK	
Electrical tests:		
Operation	OK	OK

Approved: 9/9-83

PRODUCTION RECORD

Unit	Type
Regulated Power Supply	3PROBA

Drawings

S	E4-719	Front plate:	
PL	E4-720	Label:	E4-1484
A	E4-719		

Manufacturing details

Quantity: 2 Serial no: 01-02

Toti: BC Rail 106922

Date: 2.9-83 BL

Remarks

Routine tests

	Serial no: 01	02
Visual inspection:	OK	
Electrical tests:		
Output voltage/current	OK	OK
alarms	OK	OK

Approved: 7/9-83

RS

NOKIA
CAPACITOR DIVISION

ROUTINE TEST REPORT

66.10/3.5.257 15.2.1984

Nokia Engineering/B.C.Rail

EN-23125-2656-265606-0

NOKIA
Acknowledgement No. 136526

Product	Quantity
Capacitor bank type 54USNP 13.5Mvar 13.08kV 60Hz	1 pc
Capacitor unit type USNP 251kvar 1635V 60Hz	3 pcs

Test specification

IEC Publication 143

The goods have been inspected and tested in accordance with the technical specifications, and they were found to meet all requirements stated.

The following tests have been performed on every unit type USNP 251 kvar 1635 V 60 Hz

1. Sealing test at 95°C 6 hours.
2. Capacitance measurements before and after the voltage test and tan δ - measurements after the voltage test between terminals
3. Voltage witstand test between terminals at 8.88 kV dc.
4. Disharge current witstand test on internal fuses at 2.78 kV dc.
5. Checking of internal discharge resistor.

Routine test report is enclosed.

Nokia Corporation
Capacitor Division
Quality Control

Juho Raito

9. PROTECTION AND CONTROL EQUIPMENT

PROTECTION AND CONTROL CUBICLE

INTRODUCTION

The protection and control cubicle is a floor mounted cubicle containing the required protection, metering and control circuits. The front panel of the cubicle forms the control panel including indicating instrumens, mimic diagram with control switches and a protection panel with alarm indications. The cubicle is equipped with a hinged door on the back side to allow access to the bottom entry cables and the cubicle wiring. The general arrangement of the cubicle is shown on drawing E3-680, Relay Cabinet PRC-11 Layout.

TECHNICAL SPECIFICATION

Cabinet type	PRC-11
Manufacturer	NOKIA ENGINEERING
Ambient temperature range	
- operation	0...40°C
- storage	-40...+50°C
Auxiliary power supply	125 V DC
Dimension	
Height	1600 mm
Width	600 mm
Depth	650 mm
Weight	170 kg

PROTECTION CONTROL AND METERING FUNCTIONS

Spark gap protection relay	
Type	1SG01A
Rated current	5 A
Burden	3 VA
Sensitivity	approx. 5 A
Operating time	1/2 cycle
Reinsert delay, adjustable	5-20 s
Repeated fault timer	30 min
Unbalance protection relay	
Type	1UR01A
Rated current	1 A
Burden	3 VA
Sensitivity, factory adjusted	
- alarm	0.3 A
- trip	0.6 A
Pick-up delay, factory adjusted	1 s
Overload protection relay	
Type	1TR02A
Sensitivity	see fig. 9-1
Reset time	30 min.

Operating from common aux. CT
with sustained overvoltage protection relay

Sustained overvoltage protection relay	1SV02A
Type	5 A
Rated current	3 VA
Burden	factory adjusted
Sensitivity/pick-up delay,	
- rated line current	5 A/0.1 s
- sustained overvoltage, stage I	8 A/1 s
- sustained overvoltage, stage II	10 A/0.2 s
Monitoring relay unit	1MR02A
Type	yes
Seals in alarms	LED
Alarm indication	
Reset unit	1RS01A
Type	Auto and Manual
Reset modes	
Regulated power supply	3PR08A
Type	18-30 V
Input voltage	12 V
Output voltage	7 W
Rated power	

Control switches for
- Close bypass circuit breaker
- Open bypass circuit breaker
- Close motor operated capacitor bank disconnect switch
- Open motor operated capacitor bank disconnect switch
- Local/Remote control
- Lamp check

Status indication for switchgear

Metering
- Incoming voltage, PT ratio 50 kV/120 V 0-60 kV, 250°
- Outgoing voltage, PT ratio 50 kV/120 V 0-60 kV, 250°
- Line current, CT ratio 800/5 A 0-1000 A, 250°

Remote control of switchgear via voltage free contacts	yes
Voltage free contacts for remote transmission of alarms	yes

Measuring transducers for remote transmission of indicating instrument readings

Voltage transducer	two
Type	GTU 102
Input	0-120 V
Output	0-10 mA
Current transducer	one
Type	GTU 153
Input	0-5 A
Output	0-10 mA

OPERATING DESCRIPTION

The operation of the series capacitor bank can be controlled either locally or remotely. The selection is chosen with the local/remote push button on the control panel of the protection and control cubicle.

In the local operation mode with the local/remote push button pushed in and the blue light lit the motor operated disconnect switches and the bypass circuit breaker are controlled from the green and red push buttons in the mimic diagram on the front panel of the protection control cubicle. The lights of these push buttons operate as position indicators of the switches.

The motor operated capacitor bank disconnect switches on both side of the capacitor bank are controlled by one motor only. Thus, though the mimic diagram have separate switches for the incoming and outgoing disconnect switch pushing either one of them operates both switches. The push buttons and indicating lights are connected in parallel.

The control panel is also equipped with a lamp test push button. Pushing this push button lits all lamps in the switchgear control push buttons. Lights

The control of the switchgear is interlocked to allow only safe operation sequencies. The allowed operations are as follows:

- Open and close capacitor bank bypass circuit breaker is allowed independent of disconnect switch status. The open command is overridden in case of simultaneous close command or protection relay trip operation.

- The motor operated capacitor bank disconnect switch is operable ~~in case~~ the bypass circuit breaker and the motor operated bypass disconnect switches are closed. if both

when bay A

- The motor operated bypass disconnect switch is operable ~~in case~~ the bypass circuit breaker and the motor operated capacitor bank disconnect switches are closed.

METERING

The protection control cubicle is equipped with indicating instruments for measuring of the current through and the voltage on each side of the capacitor bank. These instruments are Euronorm E96 square size moving iron type with circular scale. The metering circuits also include measuring transducers for telemetering facilities.

PROTECTION

The protection equipment of the series capacitor bank consists of 3 current transformers and associated protective relays. These current transformers measures the spark gap current, the unbalance current and the line current through the capacitor bank. The secondary current of the CT:s are fed to the protection control cubicle, where it is transformed to a lower level, more suitable for electronic relays.

The electronic relays are plug in type printed circuit boards mounted in a 19 inch rack. The controls and indications needed for normal operation are readily accessible on the front panels of the pcb:s. Due to the modular construction the time required for replacement of a relay is very short.

The protection scheme of the series capacitor bank is as follows:

- In case of spark gap flashover the spark gap protection relay 1SG01A detects the spark gap current and initiates a close command to the bypass circuit breaker. Reinsertion occurs automatically after the preset reinsertion delay time, if the line current is below rated line current. In case of a second flashover within the repeated fault time a sustained spark gap operation is recorded. This initiates a close command to the bypass circuit breaker and bypass disconnect switch and an open command to the capacitor bank disconnect switch. No reinsertion is attempted after sustained spark gap operation.

- In case of unbalance in the series capacitor bank a current will flow through the unbalance current CT. This current is detected by the unbalance protection relay 1UR01A, which initiates an alarm at stage I and a close command to the bypass circuit breaker at stage II. The sensitivity set at the factory corresponds to an overload of 5% for stage I and 10% for stage II on the remaining adjacent units at rated line current. The pick up of the relay is delayed 1 second. Automatic reinsertion is not attempted.

- The overload protection of the capacitor bank is split on two different protection relays, the sustained overvoltage protection relay 1SV02A and the thermal overload protection relay 1TR02A. The sustained overvoltage relay detects whether the line current is above rated and protects the capacitor bank for overload caused by currents in excess of 1.5 per unit. The thermal overload relay protects the capacitor bank for overloads caused by currents between 1.1 and 1.5 per unit. The operating time of both relays are current dependant and shown in fig. 9-1. The reset time for the thermal overload relay is 30 min. In case of thermal overload or sustained overvoltage relay operation a close command to the bypass circuit breaker is initiated. Automatic reinsertion is not attempted.

- The purpose of the monitoring relay unit 3MR02A is to store the alarms, control the switchgear control relays and repeat relays for remote alarms. The alarm relays are reset either automatically or manually depending on the position of the selection switch on the reset unit 3RS01A front panel. The manual reset can be performed either locally or remotely.

  In order to reinsert the bank after a permanent bypass due to a protection relay operation the alarms ~~has~~ to be reset before an insertion is attempted.

CIRCUIT DESCRIPTION

Spark Gap Relay 1SG01A, drawing E3-698

In case of spark gap flashover the capacitor bank is discharged through the spark gap. The discharge current is a heavily damped approx. 180 cps AC-current with the first peak approx. 10 kA peak.

The discharge current, fed through the spark gap and auxiliary CT:s, is converted to a voltage over resistors R9 and R10. The peak value of this voltage is rectified and detected by a Schmitt-trigger. The Schmitt-trigger triggers the oneshot ~~case~~ close pulse and starts the repeated fault time counter. The duration of the close pulse is adjustable between 5 and 20 s with potentiometer Rt2.

An reinsert command is initiated when the close pulse ends ~~if case~~ the rated line current is not exceeded. This pulse duration is approx. 1 s and controlled by another one shot.

In case of a second spark gap flashover within the repeated fault time or a missoperating bypass circuit breaker a permanent bypass command is initiated. This command is controlled by a flip-flop IC3/3-IC3/4 which is set at the first spark gap flashover and reset by the repeated fault counter IC1. In case the spark gap current is not extinguished within approx. 1 second a permanent bypass is initiated on the first spark gap flashover. This command is controlled by the delay circuit R11 C2.

Unbalance Protection Relay 1UR01A, drawing E4-701

In case of unbalance in the capacitor bank a current will flow between the midpoints of the bank through the unbalance CT. The secondary current of this CT is fed to an auxiliary CT and then converted into a voltage, which is rectified at the input of the dual overcurrent relay. This input voltage is compared to the threshold level determined by trimmers Rt3 and Rt4 respectively. In case the threshold voltage is exceeded the corresponding RC-delay circuit initiates an alarm or trip signal depending on which part of the dual relay operates.

The factory setting of the threshold levels and delay time ~~is to~~ will cause an alarm at 5% and a trip at 10% overload of the remaining adjacent capacitor units at rated line current. The time delay is set to 1 second in order to allow for unbalance current caused by switching transients.

Sustained Overvoltage Protection Relay 1SV02A, drawing E3-707

The line current measured by the line current CT is fed via an auxiliary CT to the sustained overvoltage relay input, where it is converted to a voltage. This voltage is rectified and compared to a threshold level by three different comparators. In case one of the thershold levels is exceeded the corresponding RC-delay circuit will initiate an output after the preset time delay.

The threshold levels are factory set for rated line current Rt5 at 1 PU; sustained overvoltage stage I RT4 at 1.6 PU and sustained overvoltage stage II Rt3 at 2.0 PU: The corresponding time delays are set at 0.1, 1.0 and 0.2 seconds respectively.

Thermal Overload Protection Relay 1TR02A, drawing E3-704

The voltage corresponding to the line current at the input to the sustained overvoltage protection relay is also controlling the operation of the thermal overload relay. Part of this voltage is fed to a peak detector which gives a DC-voltage proportional to the line current. This voltage controls a chain of comparators set for different threshold voltages. These comparators control the time constant of the RC-circuit formed by capacitor C6 and the output resistors of the comparators.

At line currents below approx. 1.1 PU the capacitor C6 is charged to the threshold voltage of the comparator IC8/13. As the line current increases the comparators monitoring the input voltage start to discharge the capacitor C6. As the voltage decreases to the threshold voltage of comparator IC8/2 the flip-flop IC7/4-10 is set and thus charging the capacitor C6 via transistor Q2. As the voltage in the capacitor reaches the threshold level of comparator IC8/13 the flip-flop is reset and the capacitor is ready for another discharge period.

The current dependant pulse train from the output of the above described VCO controls the memory counter IC4 via a couple of gates and a frequency divider IC6. As the memory counter IC4 counts 16 counts a "Thermal Trip" output is initiated, which initiates a close command to the bypass circuit breaker.

When the line current drops below rated current the counting mode is changed from "Up" to "Down" thus allowing the reset oscillators IC7/11-3 to control the memory counter. When the memory counter reaches its zero position the output flip-flop is reset and stops the reset counting. It can be pointed out that though the reset oscillator resets the "Thermal trip" alarm it does not reinsert the bank automatically.

Note:

The reset oscillator is equipped with a test point TP5 with which it is possible to speed up the reset counter for testing purposes. This test point ~~may~~ must not be shorted when the capacitor bank is in service.

The current line characteristic of the thermal overload relay is shown in fig. 9-1.

Fig. 9-1 Series capacitor bank protection overload time-current characteristic

APPENDIX E

HARMONIC FILTER STATION TEST RESULTS

THE FOLLOWING IS A REPORT

OF THE WORK DONE UNDER

OUR WORK ORDER 83-0140

DURING FEBRUARY 1984

Prepared By

OMEGA TECHNICAL SERVICES, LTD.

MOD

KEARNEY NATIONAL (CANADA) LTD.

69 kV 800 Amp BIL 350 ADR 69 NOM KD #5105/004/3
CAT #324511-1 Built 11/83

Contact Resistance

Main Disconnect	50 micro-ohms
Ground Switch	198 micro-ohms
HiPass Filter Disconnect	53 micro-ohms
Ground Switch	206 micro-ohms
5th Harmonic Disconnect	51 micro-ohms
Ground Switch	191 micro-ohms
Operating times approximately	6 seconds

Vacuum Breaker for Filters

JOSLYN MFG. and SUPPLY CO.

Model VBM Fault Interrupter 69 kV 300 Amp
List 3109D0092G2 SERIAL #B206265

Contact resistance	load side upper bottle	91 micro-ohms
	lower bottle	86 micro-ohms
	supply side upper bottle	75 micro-ohms
	lower bottle	69 micro-ohms

All bottles were subjected to a voltage withstand of 30 kV AC for 15 seconds. The breaker was tripped and closed using a voltage equal to 70% of 125 volts (87.5 volts).

Vacuum Breaker for Power-Factor Capacitors

All six bottles were subjected to a voltage withstand of 30 kV AC for 15 seconds. Breaker was also tripped and closed at a voltage equal to 70% of 125 volts.

MAIN CT

General Electric

Type JKW 350 50/60 HZ BIL 350 NSV 69 kV
Acc. Cl at 60 hz X2-X3 0.3 B-0.1 Thru B-2.0
X1-X3 0.3 B-0.1 Thru B-2.0
X2-X3 50/5 RF 2.0 AT 30 C
X1-X3 (X2 Open) 100/5 RF 1.5 at 30 C
Cat #759X30G12 Serial #1017662

Ratio X1-X3 Calculated 20.000 to 1
Measured 20.041 to 1

Polarity H1 + when X1+

5th Harmonic Filter CT's

Type JKW 6 50/60 Hz BIL 150 NSV 25kV
Acc Cl at 60 Hz 0.3 B-0.1 Thru B-2.0
25/5 RF 1.5 at 30 C Cat #756X50G713

North Side Serial 4867211

Ratio Calculated 5.000 to 1
Measured 5.019 to 1

Polarity H1+ when X1+

South Side Serial 4867212

Ratio Calculated 5.000 to 1
Measured 5.024 to 1

Hi Pass Filter CT's

Type JKW 5 50/60 Hz BIL 110 NSV 15kV
Acc Cl at 60 Hz 0.3 B-0.1 thru B-2.0
25/5 RF 1.5 at 30 C Cat #755X50G105

North Side Serial 4819618

Ratio Calculated 5.000 to 1
Measured 5.064 to 1

Polarity H1+ when X1+

South Side Serial 4819623

Ratio Calculated 5.000 to 1
Measured 5.049 to 1

Hi Pass Filter CT's Continued.....

Polarity H1+ when X1+

Station Service Transformer

NORTHERN TRANSFORMERS INC.

75 kVA 60 Hz 1 phase 85 C 4.0% Imp.
50 kV to 120/240 Serial B335/5 Built 1983

Tap	kV	Cal. Ratio	Measured ratio
1	57.5	239.6/1	239.5/1
2	55.0	229.2/1	229.5/1
3	52.5	218.8/1	219.1/1
4	50.0	208.3/1	208.6/1
5	46.25	192.7/1	192.9/1
6	42.5	177.1/1	177.3/1

Found and Left on Tap 4

This transformer has one end of the high Voltage winding permanently grounded, making insulation tests impossible.

5th Harmanic Filter

Reactor

R = 1.552 ohms at 2 C
Z = 114.7 ohms at 2 C

Capacitors

50 kVAR 14.4 kV Approx. 0.650 mf each

All HiPotted at 55 kV DC for 10 sec

Fuses are: Canadian General Electric
Cat #328L799GR4
15 kV 50 Amp

Hi Pass Filter

Resistor

Work by others not completed when we left the site. Resistance should be 250 ohms

Capacitors

50 kVAR 14.4 kV Approx. 0.650 mf each

Hi Pass Filter Continued....

All HiPotted at 55 kV DC for 10 seconds

Fuses are: Canadian General Electric
Cat #32BL799GR4
15 kV 50 Amps

Trip Tests

Main - Current of about 200 amps was injected into the primary winding of the CT. The Breaker tripped as required and the over current relay flagged. At the same time it was noted that the panel mounted ammeter read 100 when the primary current was at 100 amps.

Filter - Current was again injected into each of the four CT's to simulate an unbalance condition. At a low level current the respective alarms operated. as the current was increased the breaker tripped and the respective relay flagged.

For the remainder of the tests please see the attached sheets.

OVER CURRENT RELAY INSPECTION AND TEST RECORD

CIRCUIT LOCATION B.C.R. - CAPACITOR STA. CIRCUIT DESIGNATION FILTERS

RELAY PHASE OVERCURRENT PHASE OR LOCATION IN PANEL 1Ø

MFG. C.G.E. TYPE IAC STYLE NO. 77B4A FUNCTION 50/51

C.T. RATIO 100/5 P.T. RATIO —

TAP RANGE 4.0 - 16.0 INSTANTANEOUS 20-80

TIME OPERATIONS INDICATOR 2.0 - 0.2 AMPS. INSTAN. OPERATIONS INDICATOR — AMPS.

RELAY INSPECTION					
DATE	FEB 29/84				
COVER	✓				
GLASS TIGHT	✓				
GLASS CLEAN	✓				
GASKET TIGHT	✓				
RELAY CONDITION					
DUST	LT				
RUST	NIL				
IRON FILINGS	NIL				
BEARINGS STICKY	OK				
SHORTING BARS IN PLACE	OK				
CONNECTIONS TIGHT	OK				
CONTACTS					
DIRTY	NEW				
PITTED	NEW				
OPERATIONS INDICATOR					
ARMATURE FREE	OK				
TARGET FREE	OK				
INSTANTANEOUS ATTACHMENT					
ARMATURE FREE	OK				
TARGET FREE	OK				
DISC RUBBING	OK				
INSPECTOR	F.L.H.				

FORM # PRR-8110

OMEGA TECHNICAL SERVICES LTD.

OVER CURRENT RELAY INSPECTION AND TEST RECORD

CIRCUIT LOCATION B.C.R. - Capacitor Sta CIRCUIT DESIGNATION Hi Pass Filter

RELAY Unbalance Alarm/Trip PHASE OR LOCATION IN PANEL Unbal.

MFG. CGE TYPE IAC STYLE NO. 77A5A FUNCTION 61A2/61T2

C.T. RATIO 25/5 P.T. RATIO —

TAP RANGE 0.1 - 0.4 INSTANTANEOUS N/A

TIME OPERATIONS INDICATOR 2.0 - 0.2 AMPS. INSTAN. OPERATIONS INDICATOR N/A AMPS.

RELAY INSPECTION					
DATE	Feb 29/84				
COVER	✓				
GLASS TIGHT	✓				
GLASS CLEAN	✓				
GASKET TIGHT	✓				
RELAY CONDITION					
DUST	Lit				
RUST	Nil				
IRON FILINGS	Lit				
BEARINGS STICKY	OK				
SHORTING BARS IN PLACE	OK				
CONNECTIONS TIGHT	OK				
CONTACTS					
DIRTY	New				
PITTED	New				
OPERATIONS INDICATOR					
ARMATURE FREE	OK				
TARGET FREE	OK				
INSTANTANEOUS ATTACHMENT					
ARMATURE FREE	N/A				
TARGET FREE	N/A				
DISC RUBBING	OK				
INSPECTOR	FLH.				

OVER CURRENT RELAY INSPECTION AND TEST RECORD

CIRCUIT LOCATION B.C.R - CAPACITOR STN CIRCUIT DESIGNATION 5TH HARMONIC FILTER

RELAY UNBALANCE ALARM/TRIP PHASE OR LOCATION IN PANEL UNBAL

MFG. CGE TYPE IAC STYLE NO. 77A5A FUNCTION 61A1/61T1

C.T. RATIO 25/5 P.T. RATIO —

TAP RANGE 0.1 - 0.4 INSTANTANEOUS N/A.

TIME OPERATIONS INDICATOR 2.0 - 0.2 AMPS. INSTAN. OPERATIONS INDICATOR N/A AMPS.

RELAY INSPECTION						
DATE	FEB 29/84					
COVER	✓					
GLASS TIGHT	✓					
GLASS CLEAN	✓					
GASKET TIGHT	✓					
RELAY CONDITION						
DUST	LIT					
RUST	NIL					
IRON FILINGS	LIT					
BEARINGS STICKY	OK					
SHORTING BARS IN PLACE	OK					
CONNECTIONS TIGHT	OK					
CONTACTS						
DIRTY	NEW					
PITTED	NEW					
OPERATIONS INDICATOR						
ARMATURE FREE	OK					
TARGET FREE	OK					
INSTANTANEOUS ATTACHMENT						
ARMATURE FREE	N/A					
TARGET FREE	N/A					
DISC RUBBING	OK					
INSPECTOR	FLN					

OMEGA TECHNICAL SERVICES LTD.

Omega Technical Services, Ltd.
1614 - 675 West Hastings Street
Vancouver, B.C. V6B 4W3

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
WATERTOWN, MASS
FORM MH-ME178

COMPANY BC RAIL - TUMBLER RIDGE
LOCATION OF TESTS CAPACITOR STATION
EQUIPMENT TESTED 5TH HARMONIC CAPACITOR CHECK

DATE FEB 28/84
AIR TEMP. 7° OIL TEMP —
WEATHER OVR CAST & RAIN 907.
DATE LAST TEST ACCEPTANCE
LAST TEST SHEET NO.

COPIES TO

LINE NO	SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES: METER READING	MULTIPLIER	MICROAMPERES	WATTS: METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR 20°C		INSULATION RATING
1	NORTH		ROW									
2											54.3 pf x 10K	
3		1.	14	100	—	1.5	20	—	—			
4	X 1.43				2002			43	.21		= .543 mf	
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15	SOUTH		ROW									
16											54.4 pf x 10K	
17		1	14	100	—	1.5	20	—	—			
18	X 1.43				2002			43	.21		= .544 mf	
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												

REMARKS

BUS GROUNDED AT CT'S END — 1.43 VOLTS IS TO BRING MILLI AMPS & WATTS TO 10 KV EQUIVALENT

KEY TO INSULATION RATING

BUSHINGS - INSULATORS - ETC.
0 - GOOD
D - DETERIORATED
I - INVESTIGATE
R - BAD SHOULD BE REMOVED OR RECONDITIONED

1000 VOLT MEGGER TEST - ETC.
GD - GOOD
BD - DETERIORATED
II - INVESTIGATE
RD - BAD SHOULD BE REMOVED OR RECONDITIONED

WINDINGS
GD - GOOD
BD - DETERIORATED
II - INVESTIGATE
RD - BAD SHOULD BE REMOVED OR RECONDITIONED

TEST SET NO. 109 TEST BY FLN CHECKED BY FLN SHEET NO. BY-BCR-CS-4

Omega Technical Services, Ltd.
1614 - 675 West Hastings Street
Vancouver, B.C. V6B 4W3

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
WATERTOWN, MASS
FORM MH-ME178

COMPANY BC RAIL - TUMBLER RIDGE DATE FEB 28/84
LOCATION OF TESTS CAPACITOR STATION AIR TEMP 7°C OIL TEMP N/A
EQUIPMENT TESTED HI PASS FILTER WEATHER OVC EAST 5 KM 90%
CAPACITANCE CHECK DATE LAST TEST ACCEPTANCE
LAST TEST SHEET NO

COPIES TO

LINE NO	SERIAL NO	TEST BY	EQUIVALENT 10 KV READINGS: MICROAMPERES METER READING	MICROAMPERES MULTIPLIER	MICROAMPERES AMPERES	WATTS METER READING	WATTS MULTIPLIER	WATTS WATTS	% POWER FACTOR MEASURED	% POWER FACTOR CORR 20°C		INSULATION RATING
1	NORTH		ROW									
2											54.8pA x 10K	
3		1	14.5	100	-	1.3	20	-	-			
4	x 1.43				2073			37	.18		= 0.548 MA	
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15	SOUTH		ROW									
16											54.7pA x 10K	
17		1	14.5	100	-	1.2	20	-	-			
18	x 1.43				2073			34	.17		= 0.547 MA	
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												

REMARKS

BUS GROUNDED AT CT's END - 1.43 VALUE IS TO BRING RESULTS TO 10KV EQUIVALENT

KEY TO INSULATION RATING

BUSHINGS - INSULATORS - ETC
0 - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD (REMOVE OR RECONDITION)

WOOD MEMBERS - OIL - ETC
GD - GOOD
DD - DETERIORATED
II - INVESTIGATE
BD - BAD (REMOVE OR RECONDITION)

WINDINGS
WG - GOOD
WD - DETERIORATED
WI - INVESTIGATE
WB - BAD (REMOVE OR RECONDITION)

CHECKED BY ELH SHEET NO BY-BCR-CS-5

Omega Technical Services Ltd
1614 - 675 West Hastings Street
Vancouver, B.C. V6B 4W3

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
WATERTOWN, MASS
FORM MH-ME178

COMPANY B.C. RAIL - TUMBLER RIDGE DATE FEB 28/84
LOCATION OF TESTS CAPACITOR STATION AIR TEMP 7°C OIL TEMP N/A
EQUIPMENT TESTED Hi PASS FILTER, CT's 15 KV WEATHER OVT CAST % HUM 90
GE TYPE JKW-5 BUILT 1983 LAST TEST ACCEPTANCE
25/5 LAST TEST SHEET NO

COPIES TO

LINE NO	SERIAL NO	TEST KV	EQUIVALENT 10 KV READINGS: MICROAMPERES: METER READING	MICROAMPERES: MULTIPLIER	MICROAMPERES: MICRO-AMPERES	WATTS: METER READING	WATTS: MULTIPLIER	WATTS: WATTS	% POWER FACTOR: MEASURED	% POWER FACTOR: COR 20°C		INSULATION RATING
1	NORTH		SIDE -		SERIAL - 4819618							
2												
3		10	68	10	680	35	.002	.07	1.03		CHL	G
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16	SOUTH		SIDE -		SERIAL - 4819623							
17												
18		10	68	10	680	35	.002	.07	1.03		CHL	G
19												
20												
21												
22												
23												
24												
25												
26	MEGGAR		1000 + MΩ.									
27												
28												
29												

REMARKS

BUS DISCONNECTER

KEY TO INSULATION RATING

BUSHINGS - INSULATORS - ETC
0 - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD REMOVE OR RECONDITION

WOUND MEMBERS - OIL - ETC
GO - GOOD
GD - DETERIORATED
GI - INVESTIGATE
GB - BAD REMOVE OR RECONDITION

WINDINGS
WO - GOOD
WD - DETERIORATED
WI - INVESTIGATE
WB - BAD REMOVE OR RECONDITION

TEST KEY NO 109 TEST BY FLH CHECKED BY FLH SHEET NO 84-BCR-CS-3

Omega Technical Services, Ltd
1614 - 675 West Hastings Street
Vancouver, B.C. V6B 4W3

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
WATERTOWN MASS
FORM MH-ME178

COMPANY B.C. RAIL - TUMBLER RIDGE DATE FEB 28/84

LOCATION OF TESTS CAPACITOR STATION AIR TEMP. 0°C OIL TEMP. N/A

EQUIPMENT TESTED 5TH HARMONIC FILTER CT'S WEATHER LT SNOW & HUM 98

G.E. TYPE JKW 6 25 KV DATE-LAST-TEST ACCEPTANCE

25/5 BUILT 1983 LAST TEST SHEET NO.

COPIES TO

LINE NO	SERIAL NO	TEST BY	EQUIVALENT 10 KV READINGS: MICROAMPERES METER READING	MULTIPLIER	MICROAMPERES	WATTS METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR 20°C		INSULATION RATING
1	NORTH		SIDE -		SERIAL -	4867211						
2												
3		10	62	10	620	32	.002	.064	1.03		CHL	G
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16	SOUTH		SIDE		SERIAL -	4867212						
17												
18		10	65.5	10	655	33	.002	.066	1.01		CHL	G
19												
20												
21												
22												
23												
24												
25												
26	MEGGAR			10000 MΩ								
27												
28												
29												

REMARKS

BUS DISCONNECTED

KEY TO INSULATION RATING

BUSHINGS - HIGH ATTRD - ETC
G - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD REMOVE OR RECONDITION

WOOD MEMBERS - OIL - ETC
GD - GOOD
DD - DETERIORATED
II - INVESTIGATE
BD - BAD REMOVE OR RECONDITION

WINDINGS
WG - GOOD
WD - DETERIORATED
WI - INVESTIGATE
WB - BAD REMOVE OR RECONDITION

TEST SET NO. 109 TEST BY F.L.H CHECKED BY F.L.H SHEET NO. B4-BCR-CS-2

Omega Technical Services, Ltd.
1614 - 675 West Hastings Street
Vancouver, B.C. V6B 4W3

DOBLE INSULATION TESTS

MISCELLANEOUS EQUIPMENT

(SPARE BUSHINGS, INSTRUMENT TRANSFORMERS, ETC.)

DOBLE ENGINEERING COMPANY
WATERTOWN, MASS
FORM MH-ME178

COMPANY B.C. RAIL - TUMBLER RIDGE DATE FEB 28/84
LOCATION OF TESTS CAPACITOR STATION AIR TEMP. 0°C OIL TEMP. N/A
EQUIPMENT TESTED MAIN C.T. WEATHER SNOW % HUM 90%
GE TYPE JKW 350 S/N 1017662 DATE LAST TEST ACCEPTANCE
BUILT 1983 69 KV LAST TEST SHEET NO.
100/5

COPIES TO

LINE NO	SERIAL NO	TEST BY	EQUIVALENT 10 KV READINGS: MICROAMPERES (MICA) METER READING	MULTIPLIER	MICROAMPERES	WATTS: METER READING	MULTIPLIER	WATTS	% POWER FACTOR: MEASURED	CORR 20°C		INSULATION RATING
1		10	22	.1	2.2	3	.02	0.06	.27		CH+L	G
2		10	22	.1	2.2	3	.02	0.06	.27		CH & GUARD	G
3		10	5	10	50	.5	.002	.001	—	—	CH→L	G
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27	MEGGER				1000 V M Ω							
28												
29												

REMARKS

BUS CONNECTED BETWEEN DISCONNECT & VACUUM BKR.

KEY TO INSULATION RATING

BUSHINGS - INSULATION - ETC.
G - GOOD
D - DETERIORATED
I - INVESTIGATE
B - BAD (REMOVE OR RECONDITION)

DOUBLE MEGGER OIL - ETC.
GG - GOOD
DD - DETERIORATED
II - INVESTIGATE
BB - BAD (REMOVE OR RECONDITION)

WINDINGS
WG - GOOD
WD - DETERIORATED
WI - INVESTIGATE
WB - BAD (REMOVE OR RECONDITION)

109 TEST BY FLH CHECKED BY PLH SHEET NO 84-BCR-CS-1

APPENDIX D

Interim Report on Power Management of
BC Rail's Tumbler Ridge Branch Line Electrification

INTERIM REPORT ON
POWER MANAGEMENT OF
BC RAIL TUMBLER RIDGE BRANCH LINE
ELECTRIFICATION

Prepared by:

P.H. Bridge, P. Eng.
Assistant Chief Mechanical Officer

February 1985

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1. INTRODUCTION

In late 1983 British Columbia Railway commenced test running with electric locomotives on a new 130 km section of rail line in North Eastern B.C. Regular electric train operation followed in 1984.

This represented the first electrification of an integral part of the North America heavy haul freight railway system using a high voltage electric locomotive supply derived directly from an independant Public Utility electric power network. Because of the physical and contractural novelty of the electrical supply and loads, special features have been incorporated into this railway electrification to monitor electric loads and also to regulate the loading. Those features are described in this report.

2. DESCRIPTION OF RAILWAY

The Tumbler Ridge Branchline was built to provide rail access to the North East Coal Block. This branch line connects two coal mines to the BC Rail main line to Prince George and thence via CN Rail line from Prince George to the Ridley Island coal port at Prince Rupert.

The Tumbler Ridge Branchline lies east-west through the Hart range of the Rocky Mountain cordillera. The line Fig. 2.1 consists of two principle grades at a maximum 1.5 percent of 31 kms. long and one of 1.2 percent 27 kms. long, and two principle tunnels 9 km and 6 km in length.

The 130 km branchline was originally planned to be a conventional diesel locomotive hauled system. It was decided to switch to electrification when Provincial and Federal grants became available and because a high voltage power supply was convenient to the line. Electrification eliminated the need for a complex ventilation scheme in each of the two long tunnels and reduced the cost of energy used to transport the coal. These savings along with reduced maintenance costs will recoup the capital cost of electrification in a reasonable time.

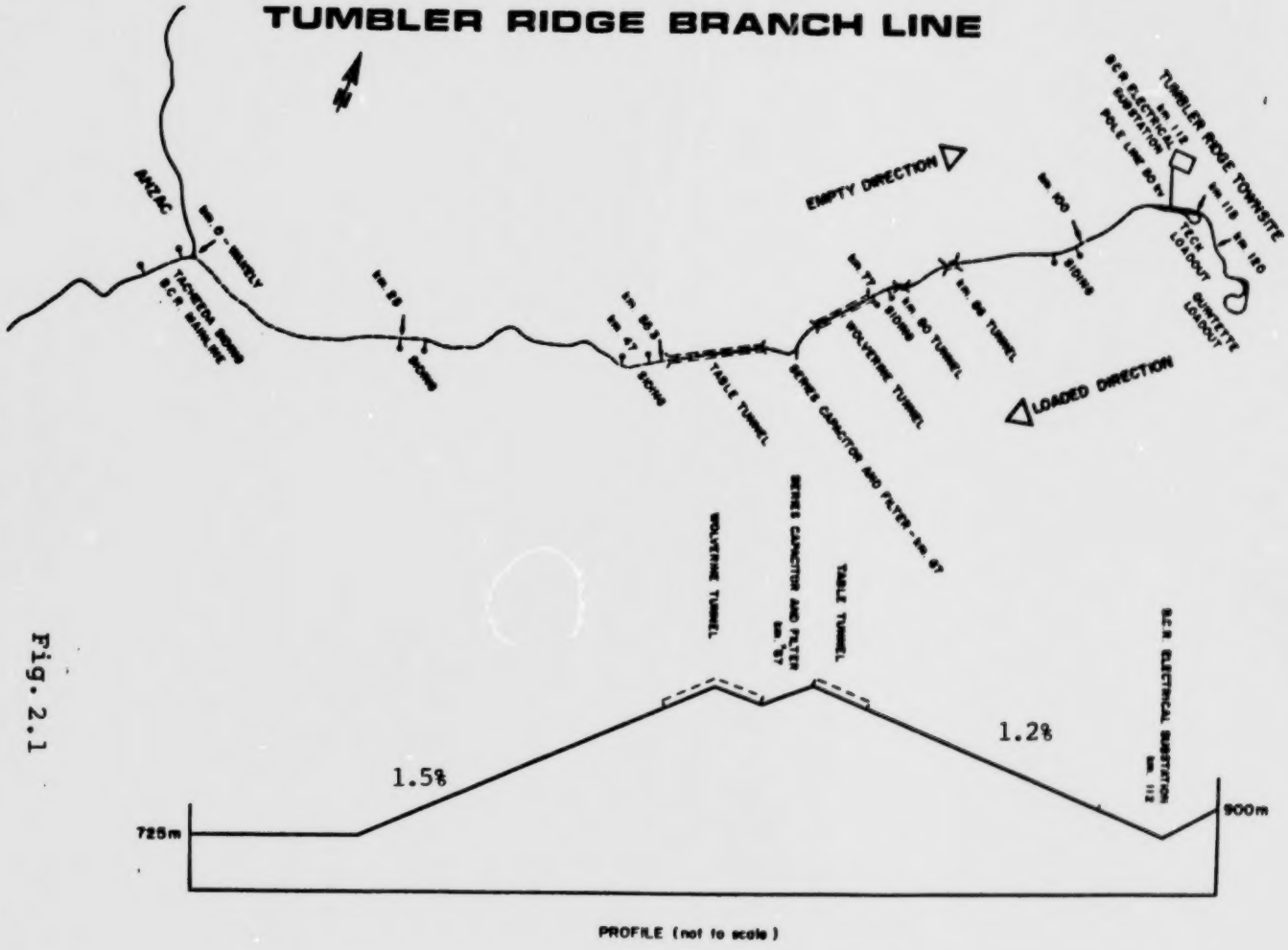

TUMBLER RIDGE BRANCH LINE
ANZAC
km 0 - WILLISTON
TACHEETA SIDING
B.C.R. MAINLINE
km 88
SIDING
km 97
km 98.3
SIDING
TABLE TUNNEL
SERIES CAPACITOR AND FILTER - km 97
WOLVERINE TUNNEL
km 77
SIDING
km 80 TUNNEL
km 88 TUNNEL
km 100
SIDING
EMPTY DIRECTION
LOADED DIRECTION
B.C.R. ELECTRICAL SUBSTATION
POLE LINE 80 KV
TUMBLER RIDGE TOWNSITE
km 118
km 110
TCR LOADOUT
QUINTETTE LOADOUT
WOLVERINE TUNNEL
SERIES CAPACITOR AND FILTER km 97
TABLE TUNNEL
B.C.R. ELECTRICAL SUBSTATION km 112
1.5%
1.2%
725m
900m
PROFILE (not to scale)

Fig. 2.1

The catenary system runs the entire length of the Tumbler Ridge Branchline including the load-out loops at both mine sites. The length of the catenary is approximately 150 kms. A single 230/50 kV substation provides power to the catenary at km 112. This permits extension eastward to future mine sites when they are developed. A capacitor station is installed at km 67 to control catenary power factor and voltage at the locomotives when they are operating at the Tacheeda end of the line.

3. DESCRIPTION OF TRAFFIC

To haul the coal from the Northeast Coal block out to Tacheeda siding in a timely manner, it is necessary to have two trains moving most of the time. These trains are either loading at the two load-out loops or are travelling between Tacheeda and Tumbler. Each train is made up of 98 coal cars plus a caboose with a total loaded gross weight of 11718 tonnes. Each train is pulled with two electric locomotives with helper locomotives added on to assist up the grade from Tumbler to the Sukunka Valley at km 69.

When the train gets to the Tacheeda siding the electric locomotives are replaced by three conventional diesel-electric locomotives for the journey to Prince Rupert's Ridley Island coal terminal.

The operational duty of six electric locomotives has been split into two functions. Four locomotives are used in pairs to travel the full length of the branchline while two are consigned to helper or "pusher" duty. The pusher duty locomotives operate together to help the loaded west bound trains to up the grade from the Tumbler siding to point mid-way between the two tunnels at approximately km 69. When the train reaches this point, the helper power is uncoupled from the train and returns to Tumbler enginehouse to wait for the next westbound train.

4. ELECTRIC POWER TARIFF STRUCTURES

4.1 Elements of Tariffs

It is a common practice world wide for corporations engaging in the generation, distribution and sale of electric power to adopt complex pricing formulas. Again, it is common practice for such corporations to hold a monopoly position in a certain geographical area and then to have prices regulated by a governmental statutes and government appointed commissioners. Approved price structures become published by order of such commissioners and generally referred to as Tariffs.

Such is the case in British Columbia where electric energy supplied by British Columbia Hydro and Power Authority (BC Hydro) is subject to tariff regulation by the Public Utilities Commission of British Columbia.

Pricing formulas as exposed in published tariffs usually have five elements:-

1. A one time up front connection charge for bringing suitable electric wires to the customer.

2. A fixed periodic charge (typically a monthly charge) considered to maintain the specific type of customer connection.

3. A charge for the electrical energy consumed by the customer, measured in scientific units.

4. A periodic charge (typically re-assessed monthly) for the greatest surge of power (i.e. horsepower) drawn by a customer averaged over short intervals of time (typically any 15 or 30 minute period).

5. Sundry other surcharges and discounts.

In fact, all elements of such a tariff have fiscal interdependence. In theory electrical energy could be sold for a single unit quantity price like gasoline out of a pump and all five elements would then be merged. With multi-element tariffs the true financial relationships are closely guarded secrets even under the scrutiny of a public Commission.

It will suffice here to point out that some aspect of up front charges can be achieved by setting minimums on a monthly bill and graduating the price of electricity as increased energy is consumed. Also the ability to supply surges of horsepower is related in part to the size of connection provided.

Surcharges or premiums may be charged if the customer's electrical load apparatus has "undesirable" effects on the power system. In scientific terms the load may dissipate electrical disturbances back over the connecting wires which cause the equipment of BC Hydro and its other customers to operate at less than optimum efficiency.

Discounts may be allowed if the customer takes electricity at very high voltage and/or provides transformers because this reduces BC Hydro costs in some manner.

In simplistic terms, the Energy charge, element 3, is considered to represent the cost of raw energy fuel used by power stations plus the operating costs of power stations and distribution system apportioned against the amount of electrical energy flowing to customers.

Again, in simplistic terms, the Demand charge, element 4, is considered to support the investment in the size of capital plant needed to support the maximum (horse) power demand placed by customers upon the system.

4.2 Standard Tariffs Applied to Railway Electrification

In considering the desirability of demonstrating Railway Electrification in a modern Canadian context and the necessity of completing the installation within an exceptionally short time of two years from consideration to operation, BC Rail and BC Hydro agreed to commence operations within the framework of available published tariffs.

This report will not address the optimum metering and tariff arrangements for electric railways. Such arrangements are currently the subject of ongoing discussions between several Canadian and US Railways and several electric power corporations involving parameters which are often regional

in nature. In British Columbia a review of tariffs is intended by BC Rail and BC Hydro after both parties have operating experience in the electric railway context and, in any event, subject ultimately to due process and review by the Provincial Public Utilities Commission.

A crucial factor in power supply, power management and power pricing derives directly from the above consideration of "demonstrating...in a modern Canadian context". This means trains made up of close to 100 cars with a gross weight of close to 12000 tonnes. To haul such trains briskly up the 1.2% grade of Tumbler Subdivision is typical of Western Canada railway needs but in electrical terms represents a very high electrical horsepower demand on the Tumbler Subdivision for relatively short periods of each day. In BC Hydro terminology this railway is said to have a low "load factor", meaning that the ratio of Energy consumed to Demand is low.

Amongst all tariffs that might be considered within Utility Commission guidelines, this low load factor means that the portion of price paid for measured Demand will equal or exceed the portion of price paid for Energy in each billing period. For clarification of this situation, it is useful to consider a large electric railway system or an industrial plant where the aggregate electric horsepower always averages out below nearly constant levels and is sustained for most of the day. In this latter case the load factor is high and the portion of price paid for Energy is far greater than the portion of price paid for Demand.

Two BC Hydro tariffs available for electric railway operation are shown in Appendix 11.1 and known as 1211 and 1821.

When applied to the electric railway the Basic Charges, initial Energy price and initial Demand price form a minor part of a typical monthly bill. The significant costs are derived from the high volume Energy price and the high level Demand price. In the case of railway load factor applied to tariff 1821 it should be noted that a special "Annual Minimum" Demand charge overshadows the apparent price benefits of the 1821 monthly Demand and Energy prices. In comparison of 1211 and 1821 (Appendix 11.2) it is

1211 which will produce the lowest monthly cost to the railway until more frequent train operations are required over Tumbler Subdivision. More frequent trains would raise the load factor to the level where 1821 produces lowest monthly cost.

The units of measure for Energy and Demand differ between tariffs. The significance of kW (kilowatt), KVA (kilovoltampere) and Demand integration intervals will be discussed further in Section 7.

5. COMPUTER SIMULATION OF POWER REQUIREMENTS

5.1 Train Performance Calculations

A large number of computer simulations (TPC or Train Performance Calculations) have been performed to represent loaded and empty trains running over the designed route and grade profile of Tumbler Subdivision. One group (Ref.1.) were performed prior to the electrification decision and a second group prior to actual operations (Ref.2). These TPC runs have included electric locomotives, diesel locomotives and trains using combinations of electric plus diesel. In addition, different train lengths were investigated. Selected TPC runs are shown in Appendix 11.3.

For planning purposes the incremental "Average Horsepower" of a TPC run was equated as one horsepower equals one kilowatt at the substation meter and one HP-HR equals one kilowatt-hour as metered. Most energy is consumed in the Wolverine Valley where transmission losses via the overhead catenary are relatively low.

From TPC runs as above, the Demand could be estimated bearing in mind that typical metering computes an average over discrete 15 minute or 30 minute periods of time.

TPC runs were also created to show the effect on overall train performance and schedule if electric locomotive horsepower is deliberately restricted. Such restriction reduces peak power load but, because of slower train speed and time integration for Demand billing, does not necessarily reduce metered Demand.

5.2 Operational Constraints on Traffic Flow

The TPC reports referenced above did not display simultaneous loaded and empty moves but these can be estimated for the very limited time frames in which significant combined Demand loading is possible within physical constraints of existing railway passing sidings. In this context, the fact that trains cannot pass in the Sukunka Valley, between tunnels, has an inherent favourable effect on Demand limitation. When train running times are adjusted to achieve loaded passing empty at either the upper Wolverine Valley siding ("Wolverine") or the upper Table Valley siding ("Whitford") one train is already within the tunnel and/or the Sukunka Valley while the other is climbing a sustained grade up Wolverine or Table.

6. SPECIAL FEATURES OF LOCOMOTIVES FOR POWER MANAGEMENT

6.1 Design of Locomotive Features

For demonstration purposes and power management capability each electric locomotive was built with three special features:

1. A line (or input power) wattmeter in the cab. The instrument is scaled in MW (megawatts) for clarity. A measurement of watts is chosen because substation Demand metering is presently based on watts. The locomotive meter could be reconnected to measure voltamps and scaled MVA if voltamp Demand metering were used and such coordination were considered desirable.

2. A switch in the cab designated "Power Limit". This switch actually inhibits turn on of the second power convertor bridge circuit so reducing maximum available horsepower to roughly one half. Inhibiting the second bridge also avoids the sharp degradation of power factor (see Section 7.2) when the second bridge is turned on and working at small firing angles (see also Appendix 11.4).

3. A four position switch back in the electronic control cabinet which operates a true horsepower limiting system. Unlike diesel locomotive convention where rated engine horsepower only yields 80-82% true horsepower at the rail for traction purposes, electric

locomotive convention rates locomotives at 100% true rail (horse)power. The four position switch can be set to limit rail power to 2600, 3200, 3800, or 4400 rail kilowatts. One rail kW equals precisely 1.34 rail horsepower or approximately 1.64 "diesel equivalent horsepower". By Manufacturers's recommendation the locomotives are not presently worked at over 3800 rail kW.

6.2 Effect of Power Restriction

Restricting locomotive power, by observing the meter (1) or switching (2) or (3), limits maximum watts that can be drawn at the substation but has the operational consequence of limiting, in direct proportion to power, the maximum speed possible at a given location while pulling the train. Restricting power has no effect on starting a train because power at starting is very low; theoretically zero at rail.

6.3 Use of Features

A loaded train is hauled by four electric locomotives, either four coupled at the front or two at the front and two at the rear. The configuration chosen is the one most expedient for operating considerations in the most cost effective use of available crews and available locomotives. Coupled locomotives receive identical electrical control signals from the chosen engineman's driving position and the electrical loading of each coupled locomotive is almost identical. Thus the wattmeter visible to the engineman represents equally the loading of each coupled locomotive and the total loading can be estimated by simple multiplication; although as described in Section 8 there is no call upon an engineman to do such arithmetic.

If locomotive rail kilowatts power is to be switch selected then it is necessary to preselect the power level in each locomotive to be used.

7. POWER METERING, RECORDING AND REPORTING

7.1 Substation Equipment

BC Rail Substation receives power from the adjacent BC Hydro Substation at 230 kilovolt (kV) with a three phase connection. All railway load is presently connected as one single phase (line to line) and transformed to 50 kV line to ground. The station service for control, battery charging and housekeeping is supplied via a separate BC Hydro connection at low voltage with its own service meter.

All BC Hydro power metering is achieved via standard metering quality potential and current transformers at the 230 kV connection busbars. A station schematic is shown in Appendix 11.5.

BC Rail metering is achieved via separate potential and current transformers at the 230 kV busbars and by potential and current transformers at the 50 kV side of the duplicate power transformers on each outgoing line. It should be noted that two outgoing lines are installed but presently tied together as one circuit for the entire railway.

At present only one of the parallel line breakers can be closed at any time and thus only one set of line metering is active.

BC Hydro recording meters are Landis and Gyr type * with an additional chart printer type * .

BC Rail metering consists of recording meters at the substation and additional transducers (see Appendix 11.6) providing input to the station Remote Terminal Unit (RTU) of the Supervisory Control and Data Acquisition System (SCADA). See Appendix 11.7. The SCADA transmits all transducer data to North Vancouver for processing as described below. The Substation is normally unattended.

The following substation recorders are equipped with visible analogue pens and rolled chart paper. Paper is normally replaced monthly.

LIST

These records provide a continuous real time record of system loading and, by manual inspection, provide a record of the line kW, volts and amps from which "power factor" may be calculated if required as below.

7.2 Definition and Effect of Power Factor

On any alternating current power system the alternating current sinusoidal wave with a frequency determined by the power generator (60 cycles per second in British Columbia) may not precisely coincide in time with the alternating voltage wave. See Fig.7.2.1. The current wave may "lead" or "lag" the voltage wave. Devices such as capacitors will create a leading current. Simple electric motors and power transmission lines usually create a lagging current. It is possible to have both leading and lagging devices connected to a supply point and bring the resultant total current wave back in coincidence with voltage. Then current and voltage are said to be "in phase". Lead and lag is expressed by wave offset or "phase angle" expressed in degrees where one full wave cycle represents 360 degrees. The energy drawn by an electric device (or true power) is mathematically determined as the product of (voltage) times (current) times (cosine of phase angle),

$$\text{i.e. power in watts} = VA \cos \phi$$

This means that if phase angle ϕ is very small then useful power is maximized at V times A. But if ϕ approaches 90 degrees then useful power is nearly zero. It is important to realize that a flow of current A, which may be substantial, is now producing no useful power or work at the connected load but it is non-the-less creating the usual current related waste of energy in transformers and in intermediate power lines. This is why Power Corporations levy a surcharge on excessive phase angles, particularly lagging which tends to predominate amongst consumers loads. Cos ϕ is usually referred to as Power Factor or p.f.

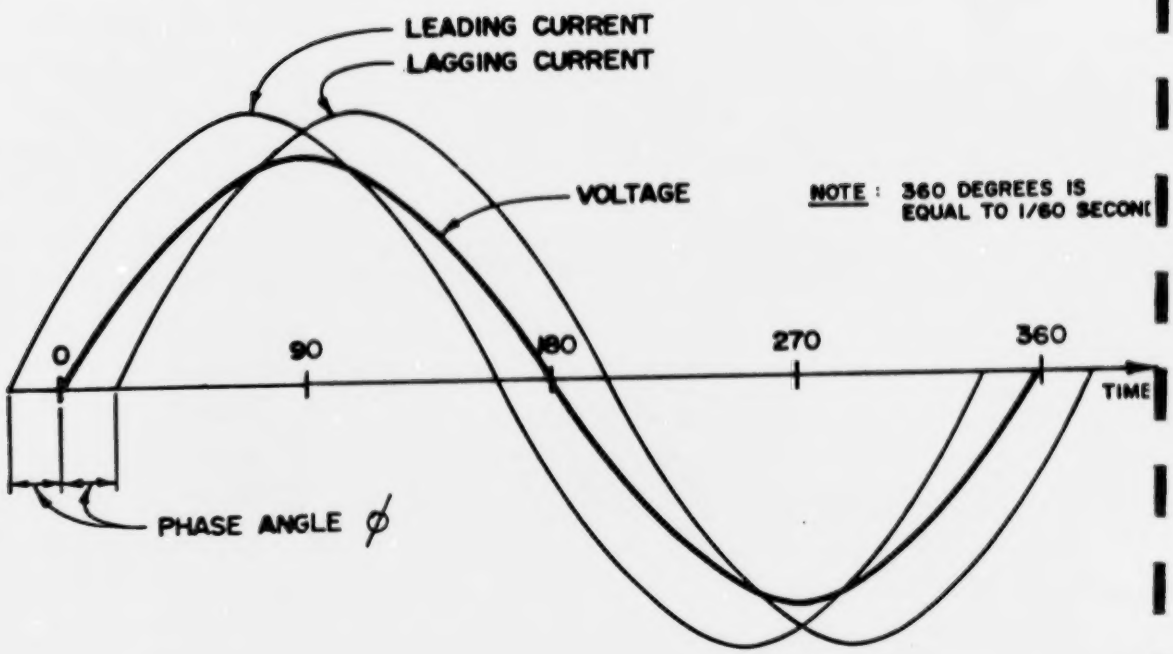

LEADING CURRENT
LAGGING CURRENT
VOLTAGE
NOTE : 360 DEGREES IS
EQUAL TO 1/60 SECONI
0
90
180
270
360
TIME
PHASE ANGLE ϕ

FIGURE 7·2·1

i.e. if ϕ = 0 degrees p.f. = 1
if ϕ = 90 degrees p.f. = 0

For tariff purposes the critical or surcharge level is usually p.f. = 0.9 which is equivalent to ϕ = 26 degrees.

If any three of the four quantities (V), (A), (W), (ϕ or power factor) are known then the fourth can be determined by simple arithmetic.

For metering purposes and tariff definitions it is sometimes preferable to measure "VAr".

In this case "Ar" is the reactive component of current expressed mathematically as A sine ϕ but three quantity metering still permits calculation of the fourth.

7.3 B.C. Hydro Metering

Energy is sold per tariff in units of kW hours or kVA hours, i.e. unit parcels of energy equivalent to one kW (or kVA) flowing for one hour.

BC Hydro meters continuously totalize kWh, kVAh and kVArh. The meters also measure average Demand over discrete 30 minute intervals in units of kW, kVA, and kVAr. The measured interval Demands each mechanically set an inert "maximum" pointer which is reset to zero by the person reading the meter each billing period (i.e. monthly). For further background data on railway load characteristics BC Hydro also run a recording Demand meter arranged to print out on paper tape each 30 minute kW Demand value. The BC Hydro meters are visible to BC Rail staff visiting the substation but have no remote reporting capability.

7.4 North Vancouver Power Coordinator and Train Dispatcher

For effective power management by BC Rail it is essential to have up to date metering data available to the Power Coordinator and train Dispatchers's office in North Vancouver. It is adequate that this data be accurate to within a few percent since it is not used for contract purposes.

SCADA operates on a polling basis wherein numerous devices at the substation and elsewhere are interrogated and read in sequence. Some priority is given to changing events and specific devices. Transducer accuracy and SCADA message content is fully adequate for metering. The limitation on absolute accuracy is frequency of the interrogation sequence in relation to rates of change of metered values between interrogation. In practice, with the SCADA adopted, updated metering information reaches North Vancouver every 8 seconds. Rates of change of electrical loading are relatively slow with large locomotives and heavy trains so that the metered values received at North Vancouver extrapolate into an adequate representation of conditions seen by substation meters and recorders.

For typical substation and North Vancouver records see Appendix 11.8.

The SCADA microprocessor at North Vancouver performs an integration of kW times hours every 15 seconds to totallize kWh and also averages kW during unit time (typically 30 minutes) to compute Demand. Unlike the substation Demand meters, the North Vancouver computation is a continuous estimate updated every 15 seconds. This is essential for power management because an impending excessive Demand must be curbed before it has occurred and registered irrevocably on the Tariff meters.

Specifically for power management purposes, the computed level of impending Demand will trip an alarm at a pre-set level and can be represented on an analogue meter in the Train Dispatcher's office.

8. POWER MANAGEMENT STRATEGY

8.1 Design Stage

Power Management strategy starts with the preparation of TFC reports as described above in Section 5. This permits electrical system design and operating costs to be estimated prior to any construction. These estimates require the creation of hypothetical train schedules for optimum and worst case conditions.

8.2 Train Schedule Variations

If all trains ran to a pre-determined schedule at all times, no further power management effort would be required except during power supply deficiencies.

However, in the "Canadian context" of coal trains travelling over BC Rail Tumbler Subdivision, schedule variations arise for many reasons, typically:

1. Delays in loading or unloading trains.
2. Traffic adjustment and incidents on the long round trip between Tumbler Subdivision and Ridley Island unloading terminal.
3. Incidents and maintenance on Tumbler Subdivision.

Schedule variation is moderated by:

1. BC Rail CN Rail agreement on distribution of train sets between railways when round trip cycles are disrupted.
2. Location of passing places in otherwise single track.
3. Maximum rate at which trains can be loaded.
4. Number of electric locomotives available, maximum six.

8.3 Active Power Management for Normal Service

Due to the moderating factors above it is feasible to target a maximum Demand for a month and experience few occasions when train schedule merits adjustment. The Demand indicator and alarm alerts the train Dispatcher on duty if a critical situation is approaching.

A BC Rail train Dispatcher has full radio contact with all trains at all times (see Appendix 11.9).

Impending excessive Demand will be arising due to the movements of two electric trains, the maximum possible on Tumbler Subdivision, and the Dispatcher can immediately speak to one or both enginemen requesting a reduction of power. This reduction can be expressed in one of three ways:

1. Reduce indicated MW on loco cab meter
2. Reduce speed (or stop)
3. Turn on power limit switches

Train adjustment involves the Dispatcher or Supervisor of Operations considering the cost of excess Demand against factors such as consequential schedule delays, crew hours, crew and train costs and revenue cash flow, all beyond the scope of this report. To assist the process it is possible to overlay the MW Demand indicator with $ cost as per tariff in effect. If Demand has been allowed to rise, the increased level is available for train operations for the remainder of the BC Hydro billing period.

8.4 Power Management for Maintenance or Supply Deficiencies

Maintenance or Defects in the Railway or BC Hydro power supply system may also result in special power management instructions. For example, a filter or series capacitor being out of service at km 67 will require locomotive power to be curbed at Tacheeda end of the line, typically with effect west of km 30. In such case a standing order will be issued to enginemen to turn on locomotive power limit switches if more than two locomotives are being worked. As a second example, if the power factor correction capacitor at the Substation is taken out of service it is possible to reduce unfavourable power factor by using the locomotive power

limit switches. This costs a slight reduction in speed during the heavy haul taking loaded trains up Wolverine Valley but prevents locomotive power converters working at the low end of the second bridge circuit in a trough of low power factor (see Appendix 11.4).

8.5 Follow Up

In normal circumstances the Substation charts and BC Hydro meters are read and reset monthly. If peculiar power demands are detected or anticipated the charts and meters can be read anytime by visiting the substation. Data thus collected provides an ongoing verification of the power management strategies adopted. Charts are recorded in real time and may be compared to all North Vancouver Power Bureau and Train Dispatching real time records if performance and strategy requires modification.

9. CONCLUSION

Power Management was incorporated as an integral part of the BC Rail Electrification of Tumbler Subdivision. The equipment and strategies meet the requirements of both electrification demonstration and most cost effective use of electric power purchased at commercial tariffs.

10. REFERENCES

1. Canadian Pacific Consulting Services Ltd., Canac Consultants Ltd., Electrification Study for British Columbia Railway Tumbler Ridge Branch Line. Transport Canada Report TP 3619E. April 1982.

2. Canadian Pacific Consulting Services Ltd., Canac Consultants Ltd., Unit Train Operations on an Electrified British Columbia Railway Tumbler Ridge Branch Line. Transport Canada Report TP 3691 E. May 1982.

11. APPENDICES

11.1 Tariffs 1211 and 1821

11.2 Comparison of 1211 and 1821

11.3 TPC Runs

11.4 GF6C Locomotive

11.5 Substation Schematic

11.6 Substation Meters and Transducers

11.7 Tumbler Ridge Branchline SCADA System

11.8 Substation Records

11.9 BC Rail Train Dispatching

APPENDIX 11.1

Tariffs 1211 and 1821

SCHEDULES 1200, 1201, 1210, 1211

GENERAL SERVICE (35 kW and over)

Availability: For all purposes. Supply is 60 hertz, single or three phase at secondary or primary potential. The Authority reserves the right to determine the potential of the service connection.

Applicable in: Rate Zone 1.

Rate: Basic Charge $3.77 per month

Demand Charge

First	35 kW of billing demand per month	Nil
Next	115 kW of billing demand per month	@ $3.02 per kW
All additional kW of billing demand per month		@ $5.79 per kW

plus

Energy Charge

First	275 kW.h per month	@ 7.20¢ per kW.h
Next	6725 kW.h per month	@ 5.31¢ per kW.h
Next	23000 kW.h per month	@ 3.93¢ per kW.h
All additional kW.h per month		@ 2.54¢ per kW.h.

Discounts

1. A discount of 1½% shall be applied to the above rate if a customer's supply of electricity is metered at a primary potential.
2. A discount of 25¢ per kW of billing demand shall be applied to the above rate if a customer supplies transformation from a primary potential to a secondary potential.
3. If a customer is entitled to both of the above discounts, the discount for metering at a primary potential shall be applied first.

SCHEDULES 1200, 1201, 1210, 1211

GENERAL SERVICE (35 kW and over) (Cont'd)

Billing Codes:

Schedule 1200 applies if a customer's supply of electricity is metered at a secondary potential and the Authority supplies transformation from a primary potential to a secondary potential.

Schedule 1201 applies if a customer's supply of electricity is metered at a primary potential and the Authority supplies transformation from a primary potential to a secondary potential.

Schedule 1210 applies if a customer's supply of electricity is metered at a secondary potential and the customer supplies transformation from a primary potential to a secondary potential.

Schedule 1211 applies if a customer's supply of electricity is metered at a primary potential and the customer supplies transformation from a primary potential to a secondary potential.

Monthly Minimum Charge: The greater of:

1. Ten dollars and sixty-nine cents ($10.69) per month, or
2. 50% of the highest maximum demand charge billed in any month wholly within an on-peak period during the immediately preceding eleven months. For the purpose of this provision an on-peak period commences on 1 November in any year and terminates on 31 March of the following year.

SCHEDULES 1200, 1201, 1210, 1211

GENERAL SERVICE (35 kW and over) (Cont'd)

Interim Increase: Effective 15 April 1984, the Rate and Monthly Minimum Charge under these Schedules include an interim increase of 6.5%, before rounding, and such interim increase may be subject to refund with interest pursuant to B. C. Utilities Commission Interim Order No. G-18-84. n

Special Condition: A demand meter will normally be installed. Prior to the installation of such a meter, or if such a meter is not installed, the demand for billing purposes shall be the assessed demand estimated by the Authority.

Special Condition: (Closed) Where electricity is supplied under Schedule 1272 for air conditioning of, or as a principal space heating fuel for the premises being supplied, and, in addition,

1. all metering is at the secondary potential on the load side of the customer's transformers, and
2. the customer provides the necessary transformers and all associated equipment other than meters, and
3. electricity supplied for purposes within Schedule 1272 is metered through a separate single meter, and separately billed on that schedule,

then all other electricity supplied at the same premises shall be metered through a separate single meter and separately billed on Schedule 1211.

This condition is available only to a customer in those premises with respect to which the Authority, prior to 1 April 1969, agreed that service would be provided under this condition and only with respect to the load which the Authority, prior to 1 April 1969, agreed to provide with service.

SCHEDULE 1821

GENERAL SERVICE - TRANSMISSION
(5000 kW and over)

Availability: For all purposes. Supply is 60 hertz, three phase at a nominal potential of 60,000 volts or higher as available. Service under this schedule will only be made available where in the Authority's opinion the customer's immediate, or immediate and prospective load is such that service at 60,000 volts or higher is required in order to conform with sound and orderly development of the Authority's electrical system.

Applicable in: Rate Zone I excluding the Districts of Kingsgate - Yahk and Lardeau - Shutty Bench.

Rate:

Demand Charge: $3.776 per kV.A of billing demand per month a

plus

Energy Charge: All kW.h per month at 1.737¢ per kW.h.

Billing Demand: The demand for billing purposes in any month shall be the greatest of:

1. The maximum demand for that month.
2. 75% of the highest maximum demand registered in any one of the immediately preceding 11 months.
3. 5000 kV.A.

Monthly Minimum Charge: $3.776 per kV.A of billing demand. a

Annual Minimum Charge: $104.65 per kV.A of the highest billing demand established in the immediately preceding period from November to February, both inclusive, in any twelve month period commencing on 1 November in any year. a

Interim Increase: Effective 15 April 1984, the Rate, Monthly Minimum Charge and Annual Minimum Charge under this Schedule include an interim increase of 6.5%, before rounding, and such interim increase may be subject to refund with interest pursuant to B. C. Utilities Commission Interim Order No. G-18-84. n

SCHEDULE 1899

WATER RENTAL ADJUSTMENT

Availability: This schedule applies to a customer who purchases electricity either:

1. Under Schedule 1821; or

2. Under a rate with the same Demand Charge, Energy Charge and Annual Minimum Charge as is from time to time contained in Schedule 1821.

Applicable in: Rate Zone I excluding the Districts of Kingsgate - Yahk and Lardeau - Shutty Bench.

Rate: All kW.h per month at 0.421¢ per kW.h. | a

Interim Increase: Effective 15 April 1984, the Rate under this Schedule includes an interim increase of 6.5%, before rounding, and such interim increase may be subject to refund with interest pursuant to B. C. Utilities Commission Interim Order No. G-18-84. | n

APPENDIX 11.2

Comparison of 1211 to 1821

K.W.	KVA.		LOAD FACTOR .05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55
6000	6315	KW.HR	219000	421000	657000	876000	1095000	1314000	1533000	1752000	1971000	2190000	2409000
		@ 1821	55678	55678	55678	55678	55678	55678	56931	61657	66779	71109	75635
		@ 1211	38208	43696	49184	54672	60161	65649	71137	76625	82114	87602	93090
		@ DIFF	+316871	+411362	+ 95894	+ 9486	- 85001	-818578	-814286	-814965	-815729	-816581	-817518
6500	6842	KW.HR	237250	474500	711750	949000	1186250	1423500	1660750	1898000	2135250	2372500	2609750
		@ 1821	59668	59668	59668	59668	59668	59668	61675	66797	71914	77024	82154
		@ 1211	41392	47337	53282	59229	65174	71120	77065	83011	88956	94901	100847
		@ DIFF	+318277	+412331	+ 96385	+ 9448	- 85505	-811450	-815389	-816215	-817041	-817867	-818693
7000	7368	KW.HR	255500	511000	766500	1022000	1277500	1533000	1788500	2044000	2299500	2555000	2810500
		@ 1821	64258	64258	64258	64258	64258	64258	66419	71933	77446	82960	88474
		@ 1211	44576	50979	57382	63785	70189	76592	82995	89398	95801	102205	108608
		@ DIFF	+319682	+413209	+ 96877	+ 9474	- 85926	-812991	-816579	-817445	-818312	-819041	-820130
7500	7894	KW.HR	273750	547500	821250	1095000	1368750	1642500	1916250	2190000	2463750	2737500	3011250
		@ 1821	68848	68848	68848	68848	68848	68848	71163	77071	82978	88886	94793
		@ 1211	47760	54620	61480	68341	75201	82061	88921	95782	102642	109502	116362
		@ DIFF	+321991	+414219	+ 97368	+ 9506	- 84752	-813212	-817757	-818718	-819663	-820615	-821569
8000	8421	KW.HR	292000	584000	876000	1168000	1460000	1752000	2044000	2336000	2628000	2920000	3212000
		@ 1821	73429	73438	73439	73438	73421	73421	75907	82209	88510	94811	101113
		@ 1211	50944	58261	65579	72897	80214	87532	94850	102167	109485	116802	124120
		@ DIFF	+322494	+415177	+ 97855	+ 9541	- 84775	-814093	-818941	-819957	-820974	-821990	-823006
8500	8947	KW.HR	310250	620500	930750	1241000	1551250	1861500	2171750	2482000	2792250	3102500	3412750
		@ 1821	78029	78029	78029	78029	78029	78029	80652	87347	94042	100737	107432
		@ 1211	54129	61982	69835	77688	85540	93393	101246	109098	116951	124804	132656
		@ DIFF	+323000	+416125	+ 98358	+ 9578	- 87199	-814974	-820125	-821207	-822285	-823364	-824444
9000	9473	KW.HR	328500	657000	985500	1314000	1642500	1971000	2299500	2628000	2956500	3285000	3613500
		@ 1821	82619	82618	82618	82618	82618	82618	85396	92485	99574	106663	113752
		@ 1211	57312	65544	73777	82009	90241	98473	106706	114938	123170	131403	139635
		@ DIFF	+325306	+417074	+ 97842	+ 9609	- 87622	-815854	-821309	-822492	-823695	-824799	-825913
9500	10000	KW.HR	346750	693500	1040250	1387000	1733750	2080500	2427250	2774000	3120750	3467500	3814250
		@ 1821	87209	87208	87208	87208	87208	87208	90140	97623	105106	112589	120072
		@ 1211	60496	69185	77875	86565	95254	103944	112634	121323	130012	138702	147391
		@ DIFF	+326712	+418022	+ 97923	+ 9743	- 86046	-816778	-822493	-823700	-824906	-826117	-827328
10000	10520	KW.HR	365000	730000	1095000	1460000	1825000	2190000	2555000	2920000	3285000	3650000	4015000
		@ 1821	91798	91798	91798	91798	91798	91798	94894	102761	110628	118494	126361
		@ 1211	63688	72827	81974	91121	100268	109415	118562	127709	136856	146003	155150
		@ DIFF	+328118	+418971	+ 97824	+ 9677	- 86469	-817617	-823677	-824947	-826217	-827485	-828753
10500	11052	KW.HR	383250	766500	1149750	1533000	1916250	2299500	2682750	3066000	3449250	3832500	4215750
		@ 1821	96388	96388	96388	96388	96388	96388	99634	107899	116170	124440	132711
		@ 1211	66864	76468	86072	95677	105281	114886	124490	134094	143699	153303	162907
		@ DIFF	+329524	+419920	+510315	+ 9711	- 89892	-819497	-824668	-826194	-827724	-829262	-830796
11000	11578	KW.HR	401500	803000	1204500	1606000	2007500	2409000	2810500	3212000	3613500	4015000	4416500
		@ 1821	100978	100979	100971	100978	100978	100978	104272	113017	121781	130546	139291
		@ 1211	70048	80189	90171	100223	110295	120356	130418	140469	150542	160603	170664
		@ DIFF	+330930	+420868	+510806	+ 9745	- 89716	-819378	-826044	-827442	-828899	-830248	-831614
11500	12105	KW.HR	419750	839500	1259250	1679000	2098750	2518500	2938250	3358000	3777750	4197500	4617250
		@ 1821	105567	105567	105567	105567	105567	105567	109117	118175	127233	136291	145350
		@ 1211	73232	83751	94270	104789	115308	125827	136346	146865	157384	167903	178421
		@ DIFF	+332336	+421817	+511298	+ 9779	- 89739	-820259	-827021	-828459	-830150	-831611	-833073
12000	12631	KW.HR	438000	876000	1314000	1752000	2190000	2628000	3066000	3504000	3942000	4380000	4818000
		@ 1821	110157	110157	110157	110157	110157	110157	112961	122581	132202	141822	151443
		@ 1211	76416	87392	98368	109345	120321	131298	142274	153251	164227	175204	186180
		@ DIFF	+333742	+422765	+511789	+ 9813	- 88163	-821129	-828412	-829996	-831461	-832885	-834310
12500	13157	KW.HR	456250	912500	1368750	1825000	2281250	2737500	3193750	3650000	4106250	4562500	5018750
		@ 1821	114747	114747	114747	114747	114747	114747	118005	128451	138897	149343	159789
		@ 1211	79600	91073	102467	113901	125235	136769	148202	159636	171070	182504	193937
		@ DIFF	+335148	+423714	+512280	+ 9846	-818586	-822028	-828586	-831184	-833772	-836260	-838748
13000	13684	KW.HR	474500	949000	1423500	1898000	2372500	2847000	3321500	3796000	4270500	4745000	5219500
		@ 1821	119337	119337	119337	119337	119337	119337	123350	135599	147829	159864	172099
		@ 1211	82784	94675	106566	118457	130348	142239	154130	166022	177913	189804	201695
		@ DIFF	+336554	+424663	+512771	+ 9880	-811810	-822901	-830788	-832421	-834083	-835734	-837386
13500	14210	KW.HR	492750	985500	1478250	1971000	2463750	2956500	3449250	3942000	4434750	4927500	5420250
		@ 1821	123927	123927	123927	123927	123927	123927	128094	136727	145361	153994	162628
		@ 1211	85967	98316	110664	123012	135361	147710	160058	172407	184755	197104	209452
		@ DIFF	+337960	+425611	+513263	+ 9914	-811433	-823761	-831964	-833679	-835394	-837109	-838824
14000	14736	KW.HR	511000	1022000	1533000	2044000	2555000	3066000	3577000	4088000	4599000	5110000	5621000
		@ 1821	128517	128517	128517	128517	128517	128517	132838	141965	154893	165920	176947
		@ 1211	89151	101957	114763	127569	140375	153181	165987	178793	191598	204404	217210
		@ DIFF	+339346	+426560	+513754	+ 9941	-811057	-824653	-833148	-834529	-836709	-838467	-840251
14500	15263	KW.HR	529250	1058500	1587750	2117000	2646250	3175500	3704750	4234000	4763250	5292500	5821750
		@ 1821	133107	133107	133107	133107	133107	133107	137582	149002	160425	171846	183267
		@ 1211	92335	105599	118862	132125	145388	158651	171915	185178	198441	211704	224967
		@ DIFF	+340732	+427508	+514285	+ 9952	-812099	-825543	-834331	-836173	-838015	-839857	-841699
15000	15789	KW.HR	547500	1095000	1642500	2190000	2737500	3285000	3832500	4380000	4927500	5475000	6022500
		@ 1821	137697	137697	137697	137697	137697	137697	142326	154141	165957	177772	189587
		@ 1211	95519	109248	122961	136681	150403	164122	177843	191562	205284	219004	232726
		@ DIFF	+342177	+426457	+514736	+ 91016	-812704	-826424	-835515	-837421	-839328	-841232	-843137
15500	16315	KW.HR	565750	1131500	1697250	2263000	2828750	3394500	3960250	4526000	5091750	5657500	6223250
		@ 1821	142287	142287	142287	142287	142287	142287	147071	159280	171488	183697	195906
		@ 1211	98703	112781	126859	141237	155415	169593	183771	197949	212127	226305	240483
		@ DIFF	+343583	+426457	+515329	+ 91058	-813127	-827305	-836499	-838468	-840437	-842406	-844375
16000	16842	KW.HR	584000	1168000	1752000	2336000	2920000	3504000	4088000	4672000	5256000	5840000	6424000
		@ 1821	146877	146877	146877	146877	146877	146877	151815	164418	177020	189623	202225
		@ 1211	101887	116523	131158	145793	160429	175064	189699	204334	218969	233605	248240
		@ DIFF	+344989	+430354	+515719	+ 91084	-813551	-828186	-837983	-839916	-841848	-843781	-845713
16500	17368	KW.HR	602250	1204500	1806750	2409000	3011250	3613500	4215750	4818000	5420250	6022500	6624750
		@ 1821	151467	151467	151467	151467	151467	151467	156559	169556	182552	195549	208545
		@ 1211	105071	120164	135257	150349	165442	180534	195627	210720	225812	240905	255997
		@ DIFF	+346396	+431902	+517410	+ 91117	-813974	-828467	-838067	-841163	-843259	-845355	-847451
17000	17894	KW.HR	620500	1241000	1861500	2482000	3102500	3723000	4343500	4964000	5584500	6205000	6825500
		@ 1821	156057	156057	156057	156057	156057	156057	161303	174594	187884	201174	214464
		@ 1211	108255	123845	139435	155025	170615	186205	201795	217385	232975	248565	264155
		@ DIFF	+347991	+433251	+518511	+ 91151	-814740	-829447	-838251	-842410	-846568	-850726	-854885
17500	18421	KW.HR	638750	1277500	1916250	2555000	3193750	3832500	4471250	5110000	5748750	6387500	7026250
		@ 1821	160646	160646	160646	160646	160646	160646	166047	179631	193216	206801	220386
		@ 1211	111439	127527	143614	159702	175789	191877	207964	224052	240139	256227	272314
		@ DIFF	+349586	+434600	+519615	+ 91186	-815243	-830229	-839435	-843657	-847879	-852101	-856323

APPENDIX 11.3

TPC RUNS

STATION RUNNING TIMES RUN NUMBER 4012.

ORIGIN = 8537.,DESTINATION = 8500.
NO OF LOCOMOTIVES = 4.,TRACTION MOTOR HORSEPOWER = 21884.0,LOCOMOTIVE WEIGHT = 780.00 TONS
LOCOMOTIVE LENGTH = 264.00 FEET, LOCOMOTIVE SPEED LIMIT = 35.00 MPH
NO OF CARS = 99.,AVERAGE CAR LENGTH = 58.44 FEET, AVERAGE CAR WEIGHT = 130.878 TONS
TRAIN LENGTH = 1.1457 MILES, TRAIN WEIGHT = 13737.000 TONS
THE ADHESION COEFFICIENT CURVE IS OF THE FORM MU=A+B*V+C*V**2+D*V**3+E*V**4
WHERE A= 0.2391E 00 B= 0.7892E-03 C=-0.4011E-04 D=-0.3702E-05 E= 0.8273E-07
THE DAVIS FORMULA IS OF THE FORM R = A + B*V + C*V**2 + D*V**3 + E*V**4
FOR THE CAR A=2.0500 B=0.0300 C=0.0005 D=0.0 E=0.0
FOR THE LOCO. A=2.0540 B=0.0300 C=0.0003 D=0.0 E=0.0
LOCO. STARTING RESISTANCE IS 20.00 UP TO 2.00 MPH

STATION NUMBER	FROM START OF RUN DISTANCE (MILES)	AVERAGE VELOCITY (MPH)	ELAPSED TIME (HRS-MINS)		AVERAGE HORSEPOWER	WORK (HP-HRS)	FROM LAST STATION DISTANCE (MILES)	AVERAGE VELOCITY (MPH)	ELAPSED TIME (HRS-MINS)		AVERAGE HORSEPOWER	WORK (HP-HRS)
8537	0.0	0.0	0	0	0.	0.0	0.0	0.0	0	0	0.	0.0
8535	3.105	24.62	0	8	14859.	1886.582	3.105	24.62	0	8	14859.	1886.582
8534	5.400	25.61	0	13	17212.	3629.164	2.295	27.08	0	5	20564.	1742.582
8533	7.400	26.34	0	17	17085.	4794.195	2.000	28.54	0	4	18823.	1185.032
8532	9.400	27.80	0	20	16022.	5417.028	2.000	34.99	0	3	10898.	622.833
8531	11.400	28.84	0	24	14383.	5684.951	2.000	35.00	0	3	4889.	287.922
8530	13.400	29.61	0	27	14873.	6639.839	2.000	34.92	0	3	18672.	954.888
8529	15.400	29.11	0	32	15525.	8213.173	2.000	26.14	0	5	20561.	1573.335
8528	17.400	27.08	0	38	15701.	10087.033	2.000	17.84	0	7	18528.	1873.860
8527	19.400	26.69	0	44	16188.	11765.857	2.000	23.87	0	5	19872.	1678.824
8526	21.400	26.14	0	48	16506.	13514.848	2.000	21.78	0	6	19032.	1748.989
8525	23.400	24.84	0	57	16370.	15422.077	2.000	18.22	0	7	15470.	1907.231
8524	25.400	23.58	1	5	16114.	17358.321	2.000	14.80	0	8	14325.	1936.244
8523	25.665	23.47	1	6	16108.	17611.204	0.265	18.48	0	1	15712.	252.884
8522	29.337	23.80	1	14	16820.	20468.242	3.672	28.34	0	8	20637.	2877.038
8521	31.400	24.19	1	18	16588.	21533.970	2.063	31.55	0	4	15991.	1045.728
8520	33.298	24.61	1	21	16333.	22099.140	1.898	34.57	0	3	10293.	585.170
8518	39.089	25.59	1	32	15545.	23742.905	5.791	33.23	0	10	9431.	1843.765
8516	41.400	25.58	1	37	14793.	23985.051	2.311	24.85	0	8	2398.	222.148
8515	43.400	25.88	1	41	14289.	23985.051	2.000	35.00	0	3	0.	0.0
8514	45.400	26.18	1	44	13819.	23985.051	2.000	35.00	0	3	0.	0.0
8513	47.400	26.46	1	47	13378.	23985.051	2.000	35.00	0	3	0.	0.0
8512	49.400	26.72	1	51	12964.	23985.051	2.000	35.00	0	3	0.	0.0
8511	51.400	26.97	1	54	12575.	23985.051	2.000	35.00	0	3	0.	0.0
8510	53.400	27.21	1	58	12209.	23985.051	2.000	35.00	0	3	0.	0.0
8509	55.400	27.43	2	1	11864.	23985.051	2.000	35.00	0	3	0.	0.0
8508	57.838	27.68	2	5	11530.	24092.275	2.438	35.00	0	4	1828.	127.224
8506	61.400	28.02	2	11	11092.	24308.003	3.564	35.00	0	6	2119.	215.728
8505	63.400	28.20	2	15	10907.	24525.181	2.000	35.00	0	3	3801.	217.188
8504	65.400	28.36	2	18	11019.	25410.363	2.000	34.82	0	3	15410.	885.172
8503	67.400	28.52	2	22	10812.	25549.210	2.000	35.00	0	3	2430.	138.847
8502	69.400	28.67	2	25	10592.	25636.148	2.000	35.00	0	3	1521.	86.938
8501	71.400	28.82	2	29	10380.	25716.528	2.000	35.00	0	3	1407.	80.381
8500	73.400	28.81	2	33	10105.	25742.574	2.000	28.53	0	4	372.	26.048

RUN 7

STATION RUNNING TIMES RUN NUMBER 5003.

ORIGIN = 8537.,DESTINATION = 8500.
NO OF LOCOMOTIVES = 4.,TRACTION MOTOR HORSEPOWER = 12000.0,LOCOMOTIVE WEIGHT = 780.00 TONS
LOCOMOTIVE LENGTH = 264.00 FEET, LOCOMOTIVE SPEED LIMIT = 35.00 MPH
NO OF CARS = 99.,AVERAGE CAR LENGTH = 58.44 FEET, AVERAGE CAR WEIGHT = 130.879 TONS
TRAIN LENGTH = 1.1457 MILES, TRAIN WEIGHT = 13737.000 TONS
THE ADHESION COEFFICIENT CURVE IS OF THE FORM MU=A+B*V+C*V**2+D*V**3+E*V**4
WHERE A= 0.2391E 00 B= 0.7892E-03 C=-0.4011E-04 D=-0.3702E-05 E= 0.8273E-07
THE DAVIS FORMULA IS OF THE FORM R = A + B*V + C*V**2 + D*V**3 + E*V**4
FOR THE CAR A=2.0500 B=0.0300 C=0.0005 D=0.0 E=0.0
FOR THE LOCO. A=2.0540 B=0.0300 C=0.0003 D=0.0 E=0.0
LOCO. STARTING RESISTANCE IS 20.00 UP TO 2.00 MPH

STATION NUMBER	FROM START OF RUN DISTANCE (MILES)	AVERAGE VELOCITY (MPH)	ELAPSED TIME (HRS-MINS)		AVERAGE HORSEPOWER	WORK (HP-HRS)	FROM LAST STATION DISTANCE (MILES)	AVERAGE VELOCITY (MPH)	ELAPSED TIME (HRS-MINS)		AVERAGE HORSEPOWER	WORK (HP-HRS)
8537	0.0	0.0	0	0	0.	0.0	0.0	0.0	0	0	0.	0.0
8535	3.105	19.83	0	9	11557.	1809.328	3.105	19.83	0	9	11557.	1809.328
8534	5.400	18.38	0	18	11885.	3432.554	2.295	16.73	0	8	11831.	1623.228
8533	7.400	19.08	0	23	11828.	4586.551	2.000	21.27	0	6	12273.	1153.997
8532	9.400	20.75	0	27	11549.	5231.658	2.000	30.67	0	4	9893.	845.105
8531	11.400	22.35	0	31	10773.	5495.884	2.000	35.00	0	3	4824.	264.228
8530	13.400	23.44	0	34	10897.	6228.888	2.000	32.54	0	4	11924.	733.004
8529	15.400	21.74	0	42	11081.	7847.918	2.000	14.84	0	8	11850.	1619.030
8528	17.400	20.01	0	52	11251.	9786.082	2.000	12.38	0	10	12000.	1938.174
8527	19.400	19.57	0	59	11350.	11253.972	2.000	16.42	0	7	12051.	1467.880
8526	21.400	18.85	1	9	11433.	13120.158	2.000	12.82	0	9	11964.	1866.184
8525	23.400	17.87	1	19	11503.	15061.420	2.000	12.38	0	10	12000.	1941.264
8524	25.400	17.28	1	28	11559.	16992.173	2.000	12.45	0	10	12017.	1930.753
8523	25.665	17.23	1	29	11568.	17228.110	0.265	13.57	0	1	12079.	235.937
8522	29.337	17.23	1	42	11626.	19797.700	3.672	17.21	0	13	12042.	2569.590
8521	31.400	17.47	1	48	11652.	20945.837	2.063	21.80	0	6	12132.	1147.937
8520	33.298	17.95	1	51	11554.	21437.033	1.898	32.83	0	3	8501.	491.398
8518	39.089	19.08	2	3	11312.	23198.436	5.791	29.83	0	12	9013.	1761.403
8516	41.400	19.31	2	9	10898.	23359.375	2.311	24.80	0	8	1727.	160.940
8515	43.400	19.72	2	12	10613.	23359.375	2.000	35.00	0	3	0.	0.0
8514	45.400	20.10	2	15	10344.	23359.375	2.000	35.00	0	3	0.	0.0
8513	47.400	20.47	2	19	10089.	23359.375	2.000	35.00	0	3	0.	0.0
8512	49.400	20.82	2	22	9846.	23359.375	2.000	35.00	0	3	0.	0.0
8511	51.400	21.16	2	26	9614.	23359.375	2.000	35.00	0	3	0.	0.0
8510	53.400	21.47	2	29	9393.	23359.375	2.000	35.00	0	3	0.	0.0
8509	55.400	21.78	2	33	9182.	23359.375	2.000	35.00	0	3	0.	0.0
8508	57.838	22.13	2	37	8987.	23486.600	2.438	35.00	0	4	1828.	127.224
8506	61.400	22.81	2	43	8729.	23702.328	3.564	35.00	0	6	2119.	215.728
8505	63.400	22.87	2	46	8627.	23919.516	2.000	35.00	0	3	3801.	217.188
8504	65.400	23.05	2	50	8890.	24874.882	2.000	30.78	0	4	11824.	755.366
8503	67.400	23.26	2	54	8809.	24928.877	2.000	34.64	0	3	4344.	250.795
8502	69.400	23.51	2	57	8472.	25012.615	2.000	35.00	0	3	1521.	86.838
8501	71.400	23.72	3	1	8338.	25082.895	2.000	35.00	0	3	1407.	80.381
8500	73.400	23.83	3	5	8157.	25119.047	2.000	28.53	0	4	372.	26.052

RUN 10

APPENDIX 11.4

GF6C Locomotive

GENERAL DESCRIPTION

The General Motors Model GF6C Electric locomotive is illustrated in Fig. 0-1. The locomotive is designed to operate as a single unit or in a multiple unit consist.

Power for operating the locomotive is obtained through a pantograph to the main circuit breaker from an overhead power supply of 50 kV at 60 Hz. Output from the circuit breaker is applied to primary windings of the main transformer.

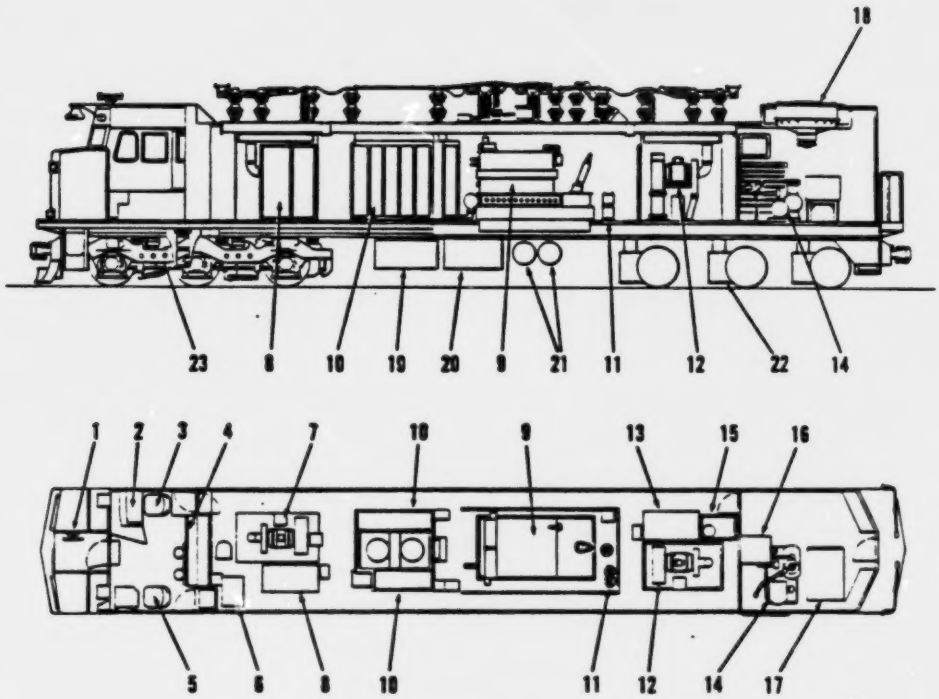
The main transformer is a fixed ratio type multiple secondary transformer. Output of the multiple secondaries is rectified and regulated by thyristor controlled convertor bridges and smoothed by reactors to provide power to the traction motors. The transformer and smoothing reactors are cooled by circulating mineral oil.

The thyristor controlled convertors for armature current, field current and auxiliary power are located in the Y1 thyristor convertor cabinet. The thyristors and rectifying diodes of the convertor units are mounted on heat sinks in unitized racks in the Y1 cabinet and are cooled by circulating oil through the heat sinks.

Power is taken from one auxiliary winding of the main transformer and applied to the APL convertor. The auxiliary power convertor rectifies this single phase power then inverts the rectified power into three phase, high speed 480 V, 60 Hz and low speed 240 V 30 Hz. This power is applied to the auxiliary equipment as required.

Auxiliary equipment includes the transformer cooling oil pump motor, traction motor blower motors, thyristor cabinet blower motors, convertor radiator blower motors, air compressor drive motor, Y1 thyristor convertor cooling oil pump and air compressor oil cooler motor.

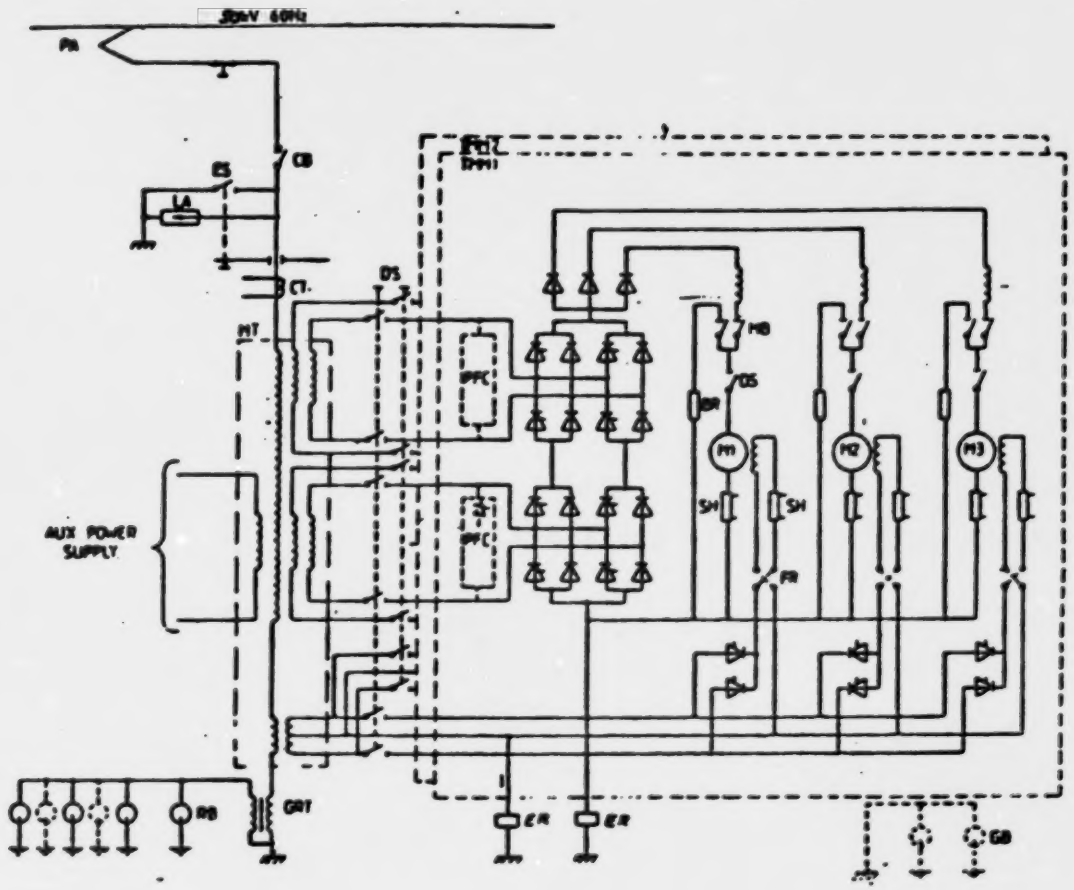
Power for the battery charger, cab heaters and machine room heaters are taken from the same auxiliary winding of the main transformer. The voltage is stepped down by an auxiliary transformer then applied to the battery charger (120 V) and heaters (240 V).



1 - Handbrake
2 - Operator's Console
3 - Operator's Seat
4 - S7 Panel
5 - Assistant's Seat
6 - Radio Equipment
7 - Traction Motor Blower
8 - Contactor Cabinet
9 - Main Transformer
10 - Thyristor Convertor Cabinet
11 - Auxiliary Transformer
12 - Traction Motor Blower
13 - Contactor Cabinet
14 - Air Compressor
15 - Auxiliary Compressor
16 - Dynamic Brake Contactors
17 - Compressor Cooling
18 - Dynamic Brake Fan
19 - Capacitor Box
20 - Filter Reactor Box
21 - Main Reservoirs
22 - Traction Motor

Fig. 1-1 - General Arrangement

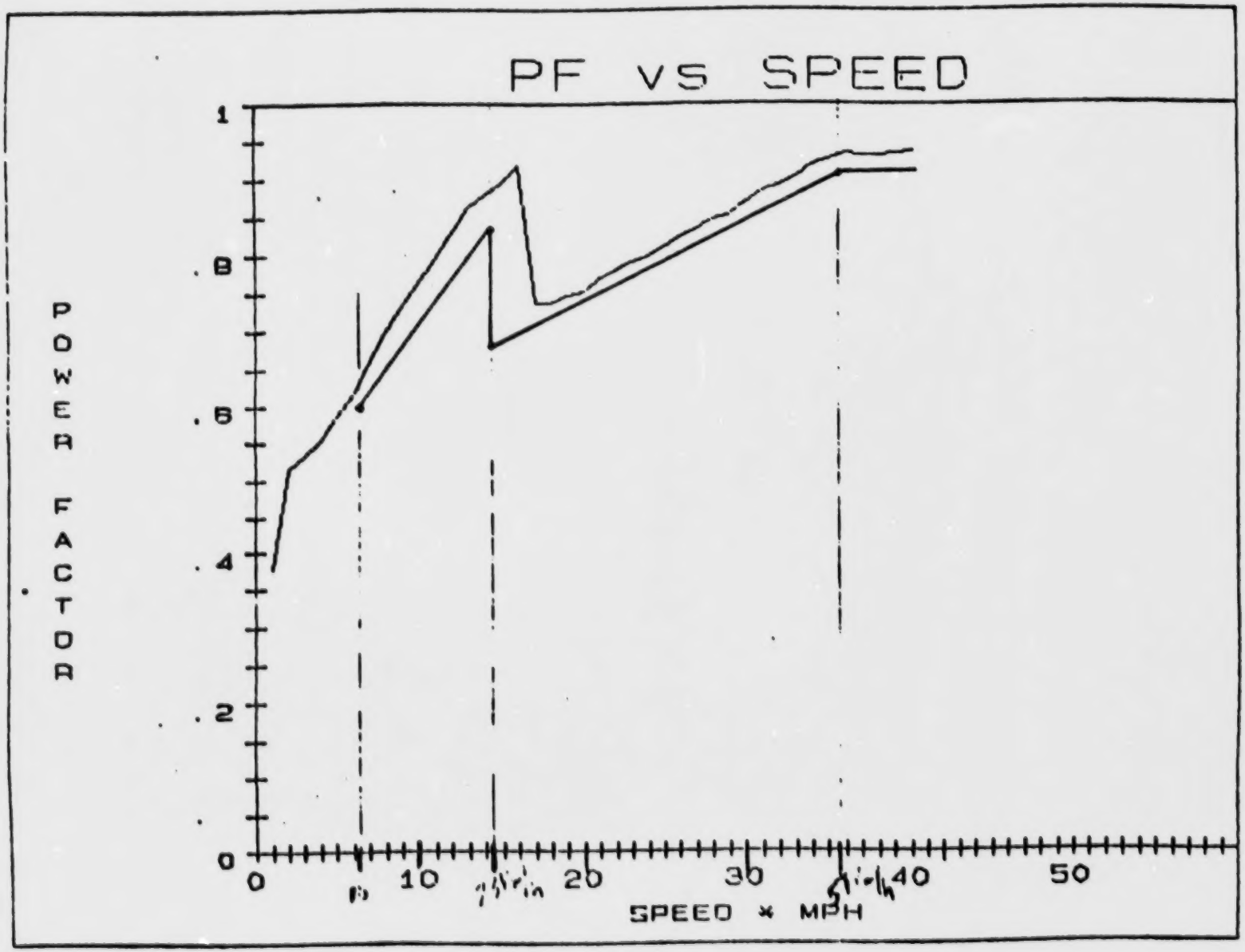
Main circuits



PA = PANTOGRAPH
DS = DISCONNECTING SWITCH
CB = CIRCUIT BREAKER
LA = LIGHTNING ARRESTOR
ES = EARTHING SWITCH
CT = CURRENT TRANSFORMER
MT = MAIN TRANSFORMER
GB = GROUNDING BRUSHES

RB = CURRENT RETURN BRUSHES
GRT = GROUNDING TRANSFORMER
ER = EARTHFAULT RELAY
TMM = TRACTION MOTOR MODULE
BR = BRAKING RESISTOR
SH = CURRENT SHUNTS
MB = MOTOR/BRAKE CONTACTORS
FR = FORWARD/REVERSE SWITCH

840227-2



SECTION 0

GENERAL INFORMATION

GENERAL DATA

Model Designation.....GF6C

Continuous Rating.....3,800 kW

Max Diesel Equivalent - Horsepower.....6,000

Main Transformer (T1)
- Cooling.....Mineral Oil
- Primary Voltage.....50 kV/60 Hz
- Secondary Voltages
  - Armature Convertor.....4 X 656V
  - Field Convertor.....2 X 200V
  - Auxiliary Convertor.....950V

Thyristor Convertor (Y1)
- Cooling.....Mineral Oil

Traction Motor (6 Total)
- Model.....E88
- Type.....Separately Excited
- Current Rating
  - Maximum Continuous.....1042 A

Maximum Continuous Tractive Effort.....400 kN @ 34.5 Km/h (90,000 lbs @ 21.5 mph)

Wheels
- Diameter.....1066.8 mm (42")
- Gear Ratio.....83:18

Auxiliary Power for Auxiliary Machinery
- Rating Full Speed.....232 kW

Main Circuit Breaker
- Type.....21CB3B2
- Voltage.....50 kV

Pantograph (2 Total)
- Model.....29200 A

Air Compressor
- Type.....Rotary Screw
- Lube Oil Capacity.....102.3 l (22.5 Imp Gal)
- Displacement Half Speed 900 RPM...1.6 m^3/min (56.2 cu ft/min)
  Full Speed 1800 RPM..3.8 m^3/min (135 cu ft/min)

Storage Battery (Calcium/Lead)
- Number of Cells.....32
- Voltage.....64
- Rating (8 hour).....280 A/Hr

Sand Total Capacity.....1.1 m^3 (40 cu ft.)

Air Brakes.....26 LUM

Brake Control Valve.....30 CDW

Loaded Weight on Rails

- Max.....180,859 kg (398,720 lbs)
- Max/Axle..... 30,445 kg (67,118 lbs)

Major Dimensions

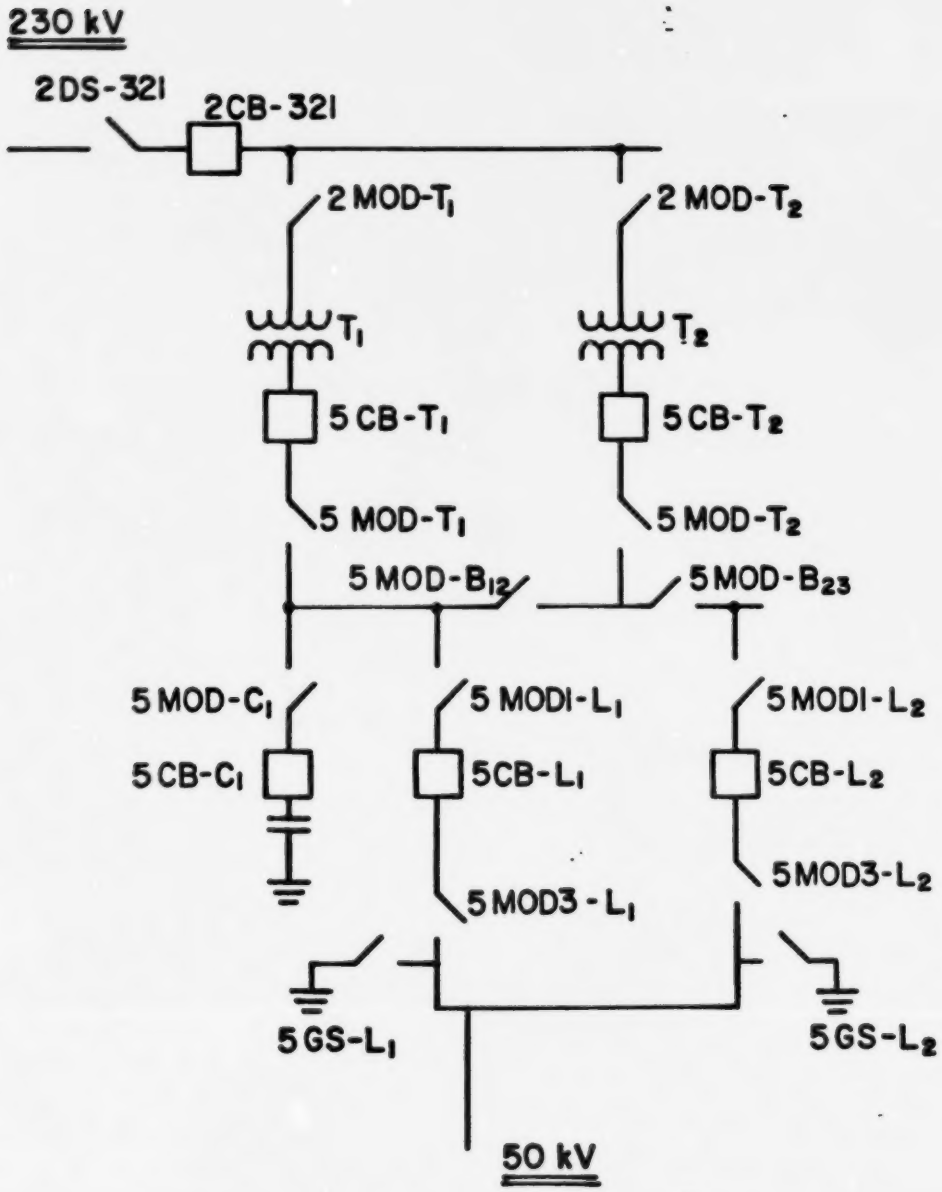
Distance
- Between pulling face of coupler and bolster centerline..... 3.86 m (12'8")
- Between bolster centerline.....13.26 m (43'6")
- Over couplers.....20,98 m (68'10")

Width
- Over arm rests..... 3.24 m (10'8")
- Over cab sheeting..... 3.05 m (10'0")

Height
- Top of rail to top of locked..... 5.03 m (16'6") down pantographs
- Top of rail to top of fully..... 7.19 m (23'7") extended pantographs

APPENDIX 11.5

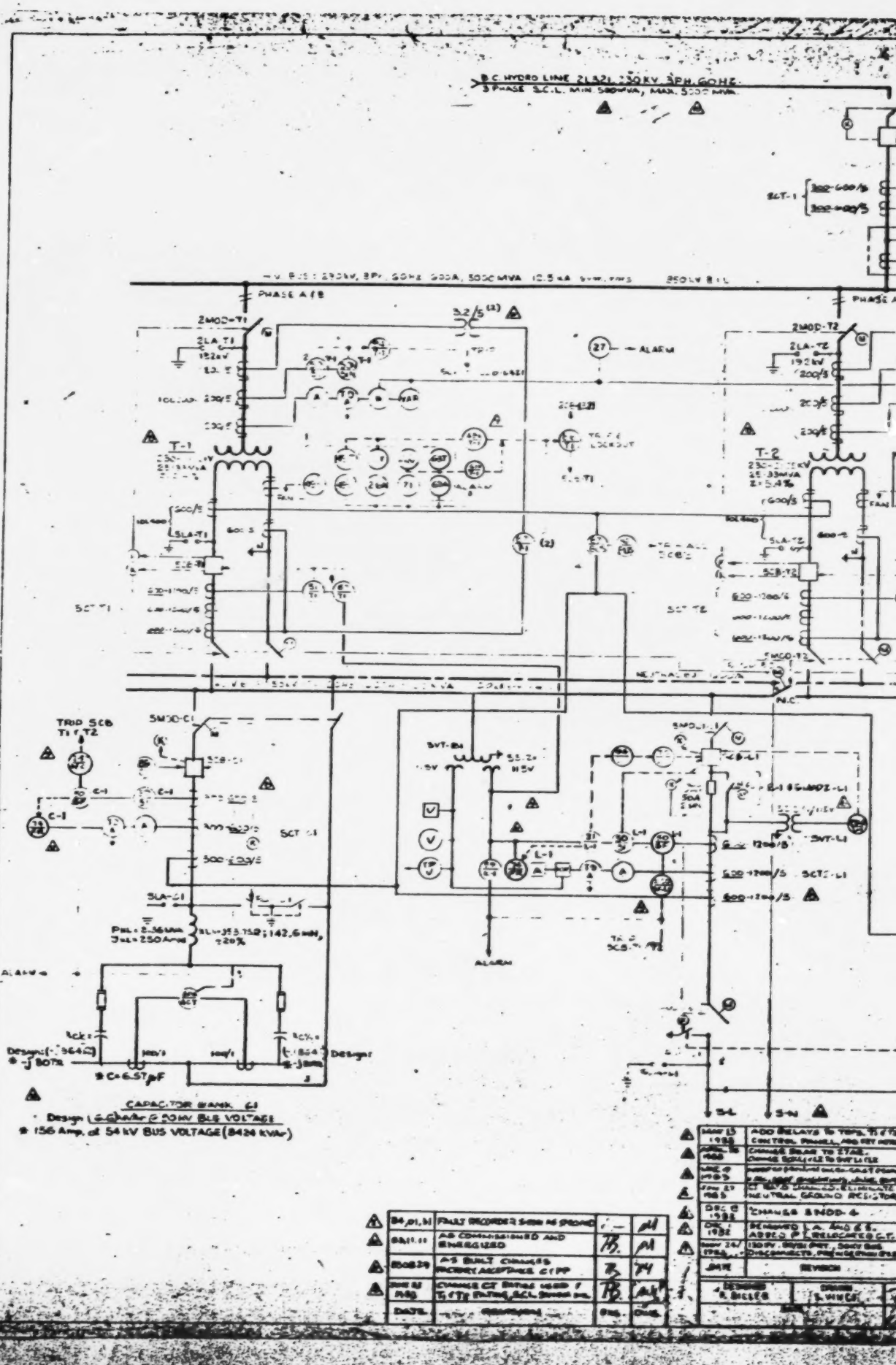
Substation Schematic

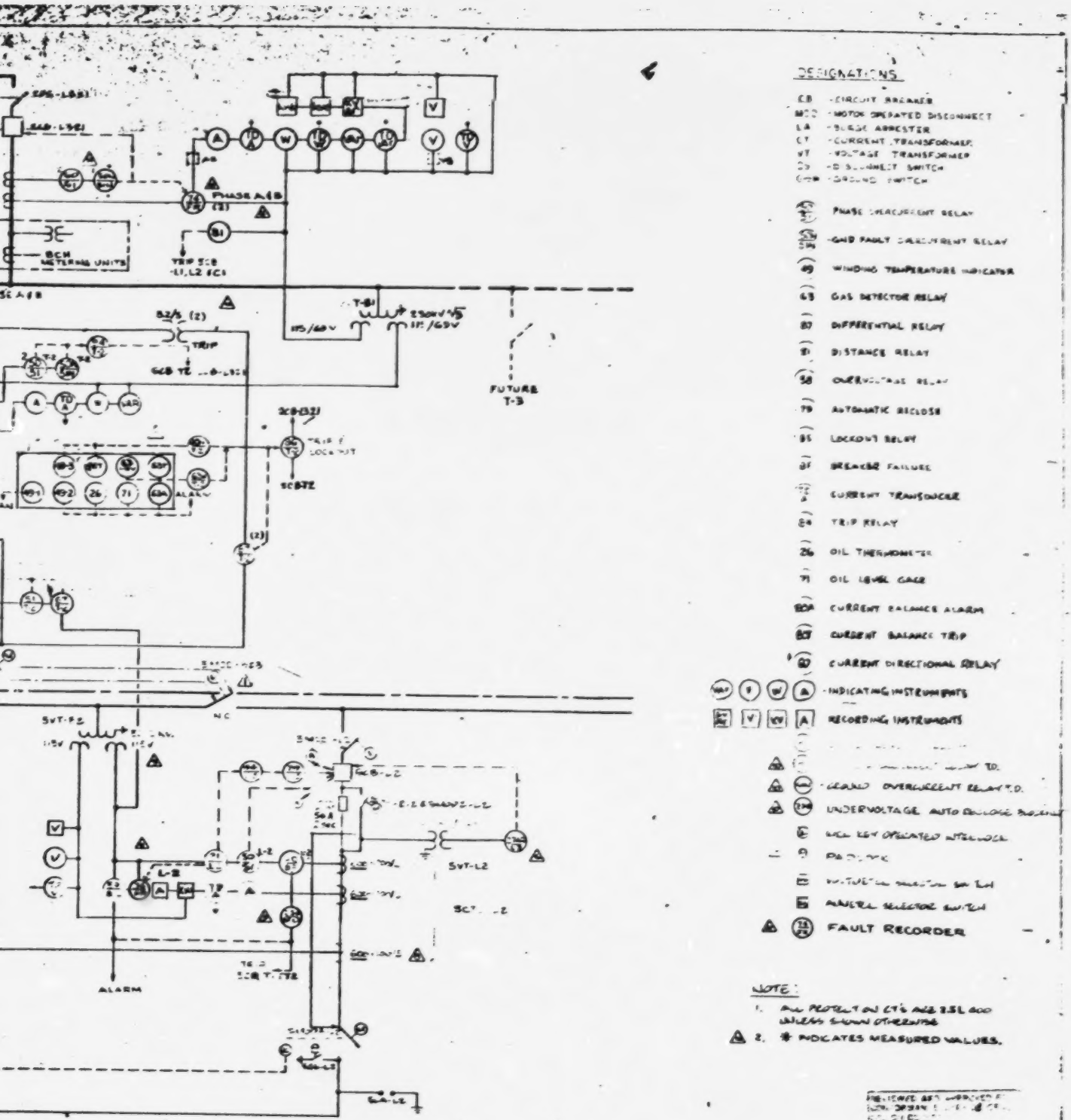


Substation Schëmatic

APPENIDIX 11.6

Substation Meters and Transducers


B.C. HYDRO LINE 21321, 230kV, 3PH, 60HZ.
3 PHASE S.C.L. MIN 5000MVA, MAX. 5000 MVA.
PHASE A/B
2MOD-T1
2LA-T1
192kV
T-1
230/5
SCT-T1
2MOD-T2
2LA-T2
192kV
200/5
T-2
230/5
SCT-T2
ALARM
TRIP SCB T1 & T2
SCB-T1
SCB-T2
SCB-C1
SCT-C1
SLA-C1
SVT-C1
SVT-L1
SCT-L1
SCB-L1
SMOD-L1
C-1
L-1
ALARM
CAPACITOR BANK C1
Design 6.6kVar @ 50Hz BUS VOLTAGE
156 Amp. at 54 kV BUS VOLTAGE (8424 kVar)
C=6.57μF



Canadian Pacific Consulting Services Ltd CANAC Consultants Ltd Swedenail Consulting Ltd.	BRITISH COLUMBIA RAILWAY ENGINEERING DEPT.	NORTH EAST COAL DEVELOPMENT TUMBLER RIDGE BRANCH LINE 230-50kV SUBSTATION PROTECTION AND METERING SINGLE LINE DIAGRAM
	83-03-8	SCALE: NONE; DATE: OCT. 14-82; DRAWING No.: C82079-20-01; SHEET: 1; REV: 4

A3/15-2045

APPENDIX 11.7

Tumbler Ridge Branch Line SCADA System

THE B.C. RAIL TUMBLER RIDGE

BRANCH LINE SCADA SYSTEM

by

Ralph Kolewe
GEC Canada Ltd.
Mississauga, Ontario

Presented to the
Canadian Electrical Association
Data, Automation & Control Subsection
1984 Spring Meeting
Toronto, Ontario
March, 1984.

1. SUMMARY

This paper describes the microprocessor based supervisory control and data acquisition (SCADA) system used on Canada's first major rail electrification project. The multiprocessor architecture, software design and user interface of this system will be discussed.

2. INTRODUCTION

The SCADA system described here was supplied to the British Columbia Railway, for its newly built Tumbler Ridge branch line, by GEC Canada Ltd. The line runs for 130 km from the coal fields at Tumbler Ridge in northeast British Columbia to Anzac, where it joins an existing B.C. Rail line servicing the new deep sea terminal being constructed in Prince Rupert. Construction of the line required that two major tunnels be built: the Table Tunnel, 9 km long, and the Wolverine Tunnel, extending .6 km. Diesel electric power would have required extensive and expensive ventilation facilities in the tunnels, which would have cost nearly $15 million. The electrification of the line avoided these costs, and is also expected to provide fuel savings estimated at two million gallons of diesel fuel annually. In addition, the life of the electric locomotives is about twice that of the diesel electric. Construction of the line began in 1981, and testing of the electric locomotives began in November 1983. The first load of coal was shipped in November 1983 using diesel electric locomotives.

The electric power system was designed by Canadian Pacific Consulting Services, in conjunction with B.C. Rail [1]. The electrified line is fed at one end by a single 230kV, 60 Hz feeder provided by B.C. Hydro from a dedicated ring bus position in their 230/25kV substation at Tumbler Ridge. All three phases are brought to B.C. Rail's 230/50kV substation, located approximately 2 km north of the railway line at 112 km. Two 25/33 MVA single phase transformers are connected between phases A and B on the 230kV side and phase to ground on the 50kV side. The two transformers normally operate in parallel to provide a hot standby and accommodate a maximum traction load of up to 35 MVA.

The SCADA system monitors the status of the manually operated disconnect on the incoming 230kV feed, and allows the remote operation of the motor operated disconnects isolating the two transformers as well as the two 230kV transformer circuit breakers. The SCADA system also monitors MW, MVAr, kV and A transducers on the 230kV bus, and calculates the 15 minute average demand and total power consumption at one minute intervals.

On the 50kV side, the transformers feed a 50kV single phase normally closed split bus. There are three 50kV breakers on this bus : one is used for the normal supply of the catenary, another serves as a standby to the catenary feeder, and the third connects a 7 MVAR shunt capacitor and reactor third harmonic filter combination.

The SCADA system allows the remote control of the feeder breakers and isolating motor operated disconnects. Voltage and current on the 50 kV side of each transformer is monitored as is the voltage on the hot side of the shunt capacitor. In addition to breaker and MOD control and transducer telemetry the SCADA system also monitors the status of alarm sensors and the reclosure lockout relays, which can be remotely reset.

A series capacitor station at 67 km serves to reduce the inductive reactance of the catenary feeders, improving the voltage profile of the load when locomotives are pulling towards the far end of the line. The -j 15 ohm, 800 A continuous rated series capacitor was designed to provide an approximate 28% line impedance compensation. The location of the station between the two major tunnels was influenced mainly by the limitations of the mountinuous terrain and a desire to achieve optimum compensation at minimum cost and maximum operating flexibility and accessibility.

The series capacitor station has bypass protection during catenary faults, and the SCADA system allows the remote operation of both by-pass and isolating motor operated disconnects as well as the bypass circuit breaker. Current through the capacitor and line voltage on both the substation and Anzac sides of the capacitor are remotely monitored as well.

Catenary sectionalizing disconnects allow the isolation of sections of the catenary west of the substation. Sidings can also be isolated. Both sectionalizing and siding disconnects are under the control of the SCADA system. In addition, the SCADA system monitors the voltage at either end of the line, at -2km and 112 km.

Normally, the Tumbler Ridge branch line power system is operated remotely via the SCADA desk at the Power Bureau in B.C. Rail's North Vancouver despatch centre. At times, local control of the substation, series capacitor station and sectionalizing or siding isolators may be carried out in the field.

3. SYSTEM HARDWARE

The SCADA system itself consists of the master station in North Vancouver, and eight remote terminal units, at the substation in Tumbler Ridge, at the series capacitor station and at six points along the line, as shown in Figure 1. The RTUs are connected via 300 baud modems on a multidrop microwave link to the North Vancouver despatch centre.

The master station is a multiprocessor configuration based on the CAMAC standard [2]. The substation RTU is also CAMAC based, while the line and series capacitor RTUs are single board CMOS micro-processor based units. The system as a whole comprises 280 status

inputs, 56 analog inputs, and 74 control outputs; of these, the substation RTU accounts for 144 status inputs, 32 analog inputs and 32 control outputs, while the line and series capacitor RTUs each have 16 status inputs and 6 control outputs. In addition, the RTUs at the series capacitor, 112km, and -2km are also each equipped for 8 analog inputs.

A block diagram of the master station is shown in Figure 2. The station consists of the following modules :

1. An auxiliary crate controller;

2. A programmable communications interface (PCI) mdoule, equipped with a data acquisition firmware package, interfaced to the RTUs via a 300 baud modem;

3. A PCI equipped with a general asynchronous firmaware package, driving two dot-matrix printers;

4. A PCI equipped with a specialized operator interface firmware package, driving two colour graphic CRTs;

5. An erasable read-only memory module;

6. A battery backed up precision time source;

7. Discrete and analog output driver modules, driving a passive mimic panel.

In the following paragraphs we shall describe the hardware backbone of the system, namely the auxiliary crate controller, the programmable communications interface, and the erasable read only memory module.

The CAMAC standards allow for multiple controllers in a single crate. The master controller located in crate slots 24 and 25 is required to latch and encode the station and LAM interrupt lines available only at these two crate positions and place them on the auxiliary control bus; the master controller need not do more than this, however, allowing the crate to be controlled solely by a group of auxiliary controllers. Daisy-chained request and grant lines are used to arbitrate contention for control of the crate.

The Trimac Auxiliary Crate Controller [3] used in the B.C. Rail SCADA system was designed with a such a multiple controller situation in mind. The design originated at TRIUMF, the meson research facility at the University of British Columbia; GEC Canada has manufactured the module for TRIUMF since 1982, and has made some modifications to the original design which make the unit more suitable to a commercial control application.

The Trimac controller is based on the 8085 microprocessor. The board has provision for up to 40K of EPROM and 24K of static RAM. It provides a single serial port, and makes the microprocessor bus available on an external connector. The CAMAC dataway interface is memory mapped, and LAMs from up to eight slot positions (stations) can be used to generate interrupts. In addition, two timers can be used as fast and slow real time clocks.

The programmable communicatons interface (PCI) modules [4] used in the B.C. Rail SCADA system are Z80 based, with a mix of up to 48K of EPROM and 8K of static RAM. Each module provides two fully configurable serial ports, capable of supporting numerous communications protocols; its dataway interface makes use of a DMA controller for fast transfers.

The erasable read-only memory (ERM) module [5] is also Z80 based. It acts as an intelligent non-volatile storage device, and its four banks of memory can be equipped with up to 128K of EPROM as program store, or 128K of EEPROM as non-volatile backing store, although only 32K of EEPROM are used in the B.C. Rail system. The ERM acts solely as a slave of the crate controller: LAMs are only generated on the completion of activities initiated by the crate controller.

The precision time source uses a temperature compensated high precision quartz crystal oscillator, driving a low power CMOS real time clock circuit maintaining the time to millisecond resolution. The clock switches to a lithium battery backup when the main power fails. In normal operation, the clock interrupts the crate controller every 100mS.

Three output driver modules are used to drive the passive mimic and audible alarm: four 48 channel high current output driver modules drive the mimic panel lamps, and two 16 channel 12 bit digital to analog converter modules drive the panel meters. Finally, a 16 channel input gate/output register module is used to drive the audible alarm.

The RTU at the Tumbler Ridge substation is also CAMAC based. It consists of the following modules, as shown in the RTU block diagram, Figure 3.

1. A Trimac auxiliary controller;

2. A PCI equipped with a general asynchronous firmaware package, configured for the variable message length (VML) message protocol used to communicate with the RTU's;

3. A discrete input matrix scanner module;

4. A 32 channel self-scanning precision analog to digital converter module;

5. A momentary control output module;

6. A 48 channel discrete output driver module.

The Trimac and PCI are identical, except for memory configuration, to those used in the despatch centre master station. The other modules are described below.

The matrix scanner [6] is a Z80 based module which scans a matrix of up to 256 optically isolated digital inputs wired to an external termination panel. The module was originally designed for a sequence of event recorder application; it has the capability to time tag changes of state to within 1 mS, and can report changes using either the actual physical status (open or closed) of inputs or a downloaded normal state mask to provide alarm/normal status. In addition, any inputs may be jumpered out, with the result that changes in these inputs do not cause an interrupt to the crate controller. In the substation RTU, the matrix scanner is used simply to generate interrupts on input status changes.

The precision analog to digital converter module (PAD) [7] is a 32 channel, 12 bit precision self-scanning unit with digital store. Inputs are converted to voltage signals by precision scaling resistors on an external transient protection module, and are scanned at a rate selectable from 32 kHz to 32 Hz. Each channel has a programmable gain.

The momentary control output module (MCO) [8] implements select/check/operate security for momentary control outputs. The module drives a panel of interposing open and close relays, with a continuous DC rating of 20A.

The discrete output driver module is identical to that used at the master station. It drives a 48 lamp mimic panel on which station alarms are annunciated.

The line and series capacitor RTUs make use of GEC's MAC 1650 mini RTU [9]. The basic single board module is based on the NSC 800 CMOS microprocessor, equipped with up to 24K of EPROM and 8K of RAM. The board also provides up to 16 status, 16 analog, and 3 frequency or counter inputs, and up to 8 double momentary and 8 direct control outputs. An expansion bus interface permits the addition of up to four 32 channel self-scanning analog to digital conversion modules, or 32 channel double momentary control output modules. The mini RTUs in the B.C. Rail SCADA system do not make use of the expansion bus, however.

4. SOFTWARE ARCHITECTURE

The system software for the B.C. Rail SCADA system is written primarily in the HP 64000 dialect of PASCAL, with interrupt handlers and critical code written in assembly language. Software development was done on a Hewlett-Packard 64000 hard disk based development system, and involved three to five people over a period of eight months.

A data flow diagram for the master station software is shown in Figure 4. Divided into three functional modules, the system software is roughly congruent with three microprocessor address spaces, as follows :

1. A database manager and report generation subsystem, resident in the crate controller;

2. A data acquisition subsystem, resident in a PCI module (PCIDAS), occupying 8K and making use of 4k of RAM;

3. An operator interface, resident in a second PCI (PCIOPI), occupying 32K and making use of 8K of RAM.

In addition, a background diagnostic subsystem resident in the crate controller reports and attempts to recover from CAMAC module failures. The crate controller software in its entirety occupies 40K and requires 24K of RAM.

The remaining PCI is equipped with a general asynchronous firmware package, acting as dual buffered RS232 ports, while the ERM behaves as a 32K non-volatile mass storage device.

The software is multitasking, using a simple round robin executive to schedule tasks, which communicate via event queues and mailboxes. CAMAC dataway and external I/O is generally interrupt driven, and modules communicate via the dataway through an extension of the message passing protocol used between tasks running on the same processor. This made interfacing the three main processors in the master station relatively simple, allowing a more sophisticated system to be built than would have been the case with a single 8 bit microprocessor.

The master station communicates with the RTUs using a proprietary variable message length (VML) communications protocol [10]. This protocol divides the communications link into an application layer and a link layer. The application layer deals only with the information field of the message, while the link layer deals with control and error detection for the asynchronous communications link.

The link layer is handled by the PCIDAS firmware. A 16-bit cyclic redundancy check (CRC) is used to provide message security. If a message with a CRC check error is received by an RTU it is ignored;

a response to a master station command which contains CRC errors will cause the master station PCIDAS to retransmit the command. This is done a maximum of three times before the communications link with the affected RTU is declared to have failed. If a valid response is received after a message retry, PCIDAS increments an error counter for the RTU; this counter is cleared when the RTU recovers from a communications failure or is first inserted into the scan cycle.

In addition to handling the link layer of the VML protocol, the PCIDAS polls the RTUs regularly. Normal polling sequence for the B.C. Rail system is as follows : all RTUs are scanned for status changes, the substation RTU being scanned after each line RTU is scanned, then one RTU is scanned for analog data, and finally a failed RTU (if any) is polled for recovery. The PCIDAS also passes any control commands from the crate controller directly to the RTU, interrupting the polling cycle to do so.

Status change and analog data collected by the PCIDAS are passed on to the crate controller, which maintains a live database in RAM containing the current state as well as configuration information for every point in the system. This database is initialized from the ERM at startup; the ERM copy can be updated by the operator whenever a change is made to the system configuration, as when an analog limit value is altered or a point normal state is changed. In addition, the ERM copy of the database is updated whenever a control action is performed, so system restart is always done with the latest current state of the system.

Alarm data, such as unauthorized status changes and analog limit violations, are used by the crate controller to format time-tagged alarm messages, which are sent to the PCI driving the alarm logging printer, and the PCIOPI for display on the two operator terminals. Alarm messages are queued according to the priority of the alarm, which may be classified as either major or minor. A major alarm causes an audible alarm to sound, and requires an operator acknowledgement, while a minor alarm is merely logged. Logging of the return to normal from the alarm state can be optionally specified for both major and minor alarm points. The alarm priority, specification for logging of return to normal, and definition of normal state as open or closed can be defined online using a configuration editor.

The live database is continuously accessed by the PCIOPI to update the current screen display, if it contains dynamically changing information. PCIOPI may also request station and point names from the crate controller, which retrieves them from the ERM. The ERM is also used to store static display backgrounds and dynamic foreground definitions for graphic displays, which can be defined online using a graphic editor firmware package resident in one of the two operator terminals, in conjunction with the PCIOPI firmware package.

PCIOPI also manages control operation, together with the crate controller. Control points may be tagged to prevent operation, and the crate controller emulates in software the control interlocking scheme implemented by the protection hardware at the substation to prevent switching MODs under load. In addition, control actions are checked back both at the level of interposing relay contacts, and at the device status level.

The software in the substation RTU is simpler than the master station, as the operator interface consists solely of a passive mimic panel, and the RTU need only respond to messages sent from the master station as the VML protocol does not provide for unsolicited messages from the RTUs. With the exception of protocol decoding, which is done by the PCI, and status input scanning, which is done by the matrix scanner, the functionality of the substation RTU resides solely in the crate controller. The requisite software occupies 24K and uses 8K of RAM.

The mini RTU firmware package is written entirely in Z80 assembler, and occupies approximately 8K, using 4K of RAM. The same multitasking executive is used as in the CAMAC based units, and the software implements analog limit checking using 12 bit limit values downloaded from the master station.

5. THE USER INTERFACE

The user interface to the B.C. Rail SCADA system consists of two colour graphic CRT terminals, two printers and a passive mimic panel. These three elements provide the power coordinator with a picture of the current state of the system, a historical record of its past state, and a means to control its future state. Here we shall describe the function of each element of the user interface.

The passive mimic panel depicts the system single line diagram in two sections : one is dedicated to the substation, and the other represents the catenary. Every breaker and MOD under the control of the SCADA system is shown on the mimic by a group of three lamps, indicating whether the device is open or closed (red or green), or currently selected for control (flashing yellow). By flashing, the lamps also indicate an alarm condition on a controlled device : for example, a closed MOD which does not respond to an opening control action is indicated after 20 seconds by a flashing red lamp, while a circuit breaker tripped by a fault condition is shown immediately by a flashing green lamp. The mimic panel also includes analog meters for all transducer inputs monitored by the SCADA system, such as feeder voltages and currents at the substation, and the voltage at either end of the catenary. Thus the mimic provides the power coordinator with a summary at a glance of the current electrical state of the line.

A more detailed view of the system can be obtained using the two colour graphic CRT terminals. The available displays are hierarchically ordered, as shown in the tier chart of Figure 5. A display directory gives access to three graphic displays. One provides a summary of all transducer inputs to four significant figures, a second shows the catenary single line, indicating both device and RTU communications status, and the third shows the substation single line with all controlled devices and transducer inputs. The power coordinator also has access, via the configuration editor, to tabular summaries of the current as well as the expected state of every discrete input in the system, and all limit and current values of analog inputs. Finally, the power coordinator can view reports of all points currently in alarm, as well as the previous 72 major or minor alarms, and can schedule periodic reports of the current value of all analogs or all points in alarm to be printed on the report printer every 15 minutes, 30 minutes, hour, eight hours, or daily at a specified time.

The SCADA system is oriented around the use of the two colour CRT displays as the sole system control devices. Each operator terminal displays 48 lines of text, 80 columns wide. Every display is divided into three areas, as follows :

1. The first two lines of the display are reserved for system messages, specifically the most recent point to go into the major alarm state, the current terminal and printer mode if disabled, i.e. PRINTER DISABLED or CONSOLE ASLEEP, and the current date and time of day, updated every second.

2. The next 35 lines are used by the currently active task for tabular or graphic displays.

3. The last five lines display error messages, input prompts and softkey labels.

The operator's interaction with the system centers in this last area. The operator interface incorporates the notion of 'directed syntax': rather than a bewildering array of 45 or more dedicated function keys which must be pressed in a special sequence, the operator is presented with a limited number of continuously redefined 'soft' keys, which reflect all the syntactically meaningful options available at any given time. When a softkey followed by the return key is entered, the system responds by performing the desired action, or, if further operator input is required, by relabelling the softkeys to indicate the choices available. For example, when operating a control, the system implements a select/check/operate sequence at several levels. This extends to the operator interface. Controls can only be actuated from the two single line graphic displays. Several softkeys are defined for these displays, including a 'Control Select' key. When the operator presses this key, the prompt "POSITION CURSOR ON SELECTED POINT"

appears above the softkey label line. The operator must then select a point by positioning the cursor on the symbol corresponding to the desired device, using either the cursor movement keys or a light-pen. Once the point has been selected, the master station checks the control selection for validity, and sends the control select command to the RTU if the selection is permitted. Only if the RTU returns a select confirmation, (indicating that the correct interposing select relays have closed), will the softkeys be redefined to allow the operator to operate or cancel the control. Thus the operator is never presented with potentially confusing, invalid, or dangerous input options.

At times, the operator may be required to enter alphanumeric data, or select a point from a tabular display. A message will appear on the operator prompt line asking for the appropriate input. Alphanumeric input is echoed to the command line, and may be edited using the DEL CHAR key. Input is not processed until the return key is pressed, so the DEL CHAR key may also be used to delete an inadvertent softkey entry.

6. CONCLUSION

The Tumbler Ridge substation was energized in early November 1983; the substation RTU was installed at that time, and the master station in the North Vancouver despatch centre was placed in service in January 1984. The catenary and series capacitor RTUs were delivered in October 1983 to be commissioned in spring of 1984.

The supervisory systems GEC is scheduled to deliver in the spring and summer of 1984 to the Towns of Leduc and Rocky Mountain House in Alberta build on the basic SCADA functions in the B.C. Rail System. The memory capacity of the Trimac controller has been expanded to 96K of bank switched EPROM and RAM to incorporate additional specified features, such as online modification of RTU point capacity. The Alberta systems requirements necessitated the control interlocks and derived point capabilities of the B.C. Rail system being upgraded to permit the user to define general interlock conditions and derived point equations online. Automatic control functions have been added to give these systems a full process control capability for such functions as automatic pump control sequencing.

ACKNOWLEDGEMENTS

Many people were involved in the specification, design, construction and testing of this system, and one can do little more than list their names here : in the Digital Systems group at GEC Canada, Don Anderson, Jeff Dawkins, Pat Dawson, Pete Little, Ivo Pazzelli, John Sherwin, Peter Stower and Kam Wong; at Glenayre Electronics, Jim Boyd, George Ferris and Gerhard Herzig; at Canadian Pacific Consultants, Peter Biller and Gabor Furst; and at B.C. Rail, Peter Bridge.

NOTES

1. P. Bridge and G.T. Fisher, '50kV Electrification of the Tumbler Ridge Branch Line", a paper submitted to the IEEE/ASME Joint Railroad Conference, April, 1984.

2. CAMAC is defined by a number of standards, including ANSI/IEEE 583 (1975), ANSI/IEEE 586 (1976), ANSI/IEEE 675 (1979), and ANSI/IEEE 683 (1976). A comprehensive introduction to CAMAC is given in P. Clout, "A CAMAC Primer", Los Alamos National Laboratory Report LA-UR-82-2718, 1982.

3. GEC Canada Ltd. Technical Manual for Auxiliary Crate Controller CAMAC Module 160108, 1983.

4. GEC Canada Ltd. Technical Manual for Programmable Communications Interface CAMAC Module 160901, 1982.

5. GEC Canada Ltd. Technical Manual for 128K Byte EPROM/EAROM Memory CAMAC Module 160107, 1983.

6. GEC Canada Ltd. Technical Manual for 256 Point Contact Input Matrix Scanner CAMAC Module 160202, 1983.

7. GEC Canada Ltd. Technical Manual for Precision A/D Converter CAMAC Module 160404, 1983.

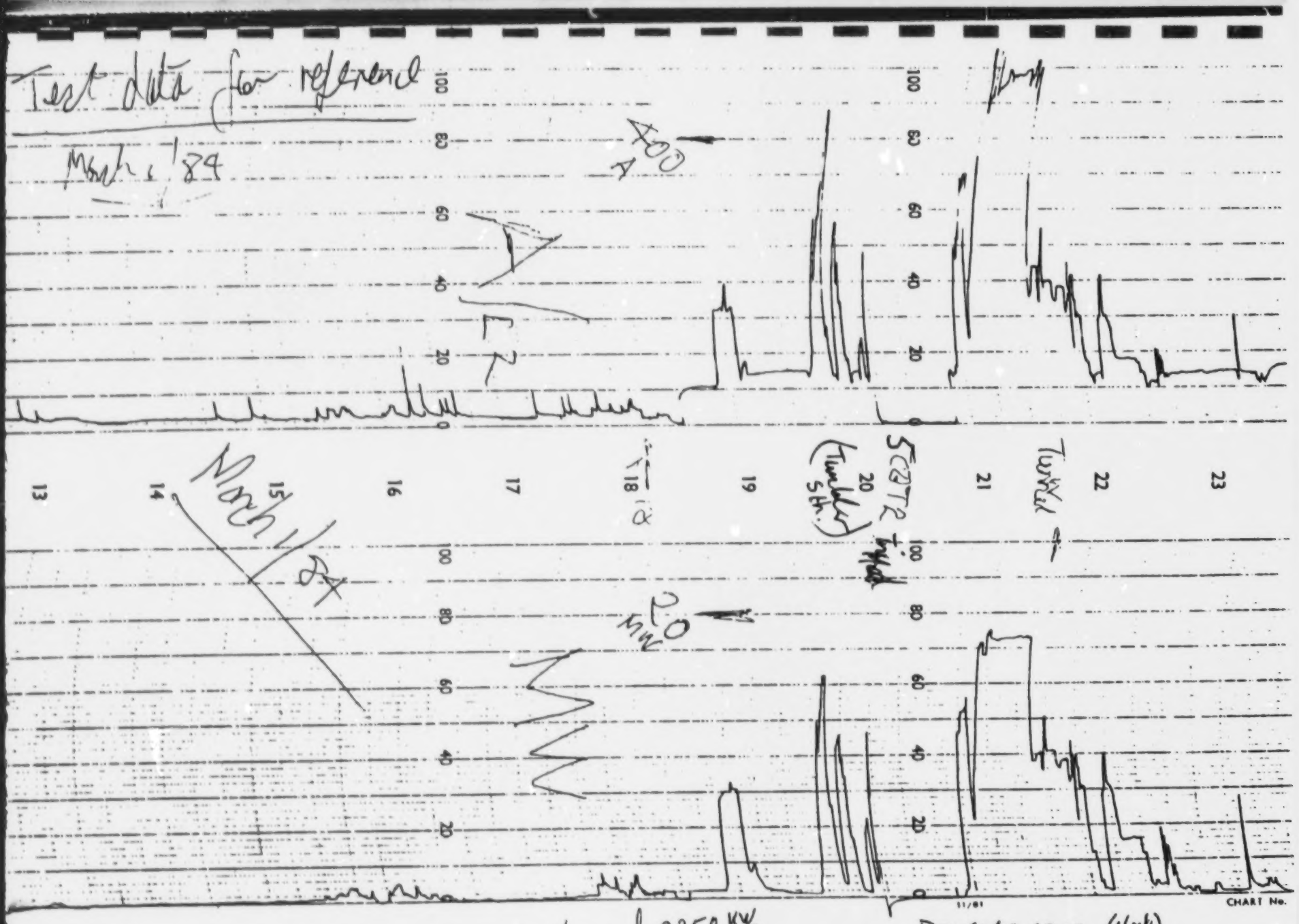
8. GEC Canada Ltd. Technical Manual for Momentary Control Output CAMAC Module 160302, 1983.

9. GEC Canada Ltd. Technical Manual for Main Processor Board MP 165101, 1983.

10. GEC Canada Ltd. MAC 1600 SCADA System Master Station - Remote Terminal Unit Communication Message Structure and Variable Message Length Protocol Description, 1984.

APPENDIX 11.8

Substation Records


Test data for reference
March 1 '89
400 A
Scott tripped (Tuesday 5th.)
Turbine
20 MW
March 14
13
14
15
16
17
18
19
20
21
22
23
0
20
40
60
80
100
11/81
CHART No.
meter demand 8350 KW
meter 8600 KVA
8900 KVA
Power on 20.40 (clock)
elec Water turned 21.28

APPENDIX 11.9

BC Rail Train Dispatching

Road Operation

Road operation is essentially the operation of trains between terminals. Such movement is under the direction of train dispatchers, who must be familiar with the physical characteristics of the portion of the railroad in their charge. They are responsible for issuing, transmitting and recording train orders as prescribed by the rules, and for issuing such other instructions as are required for the safe and efficient movement of trains. The train dispatcher further exercises control of trains via the operators who are responsible for the delivery of train orders and the messages to the persons addressed.

On certain portions of the railway the method used by the train dispatcher to control train traffic is "Manual Block" in compliance with the Uniform Code of Operating Rules. Under the Manual Block Rules, the train dispatcher issues block clearances which are the authority for a train to occupy a specific section of track.

These instructions are despatched by radio and written on a prescribed form by the conductor and engineman of the train or trains addressed and must be read back to the despatcher to ensure accuracy. If necessary, to provide for the movement of an opposing or following train, the first train must be secured and issued "restrictions" before the second train is issued instructions which allow it into the Block.

This train control is set up via the use of radio from the central train dispatching office in North Vancouver.

The central train dispatching office in North Vancouver also controls, through a CTC (Centralized Traffic Control) board the movement of unit coal trains from Hydro Jct. on the CNR to Roberts Bank.

Source: British Columbia Railway. Report to the Royal Commission. Volume 2, May 1977.

APPENDIX E

Operating and Maintenance Summary,
Tumbler Subdivision, BC Rail

OPERATION & MAINTENANCE SUMMARY

TUMBLER SUBDIVISION

BC RAIL

March 1986

The contents of this report reflects the views of the authors and not necessarily the official views or policies of the Transportation Development Centre or Transport Canada.

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INTRODUCTION

The first electrically powered unit trains were operating on the Tumbler Subdivision (previously known as the Tumbler Ridge Branch Line) in December, 1983. The construction in 1983 was from km 24 to the east end of the branch line at the two mine sites. During 1984, construction was completed to the Tacheeda siding on the BC Rail mainline.

The unit trains consist of two 6000 hp electric locomotives, 98 coal cars and a caboose. Two additional 6000 hp electric locomotives are used to push the loaded trains up the long grade between km 97 and km 72. The pusher locomotives stay with the train between the sidings at km 118 and km 70.

When the trains reach the Tacheeda siding, the electric locomotives are replaced with three 3000 hp diesel-electric locomotives for the trip to Prince George. At Prince George, the trains are interchanged to CN Rail for the westward trip to Ridley Island at Prince Rupert.

The costs of operating and maintaining the electrification system during 1985 are summarized in this report. Some costs are still left as estimated costs for a number of reasons. These include, but are not limited to: development work being done on the electric locomotives resulting in the use of some diesel locomotives at the beginning of the year, and maintenance procedures and schedules for the catenary system being reviewed.

OPERATING COSTS

Operating costs of the electrical system is the cost of electrical energy. Costs used here are based on a T.P.C. (Train Performance Calculator) model created at BC Rail. Quantities derived from this model are proving to be accurate.

Based on a current price of $0.02635 per kilowatt hour, the electric energy cost for the 27.8 megawatt hours of electrical energy is $733. In addition to the electrical energy cost, there is an additional demand charge based on peak loading. On the Tumbler Subdivision, this will occur when a loaded train and an empty train are travelling uphill at the same time. The T.P.C. shows that the peak demand for a 30 minute period for the loaded train is 8.98 megawatt hours and the peak demand for a 30 minute period for the empty train is 3.58 megawatt hours. This is a total of 12.56 megawatt hours. Under the terms of BC Rail's contract with the power utility, the maximum demand payable is 10.0 megawatt hours at a cost of $5.90 per month per kilowatt hour demand. The demand charge is irrespective of the number of trips. Table 1 shows the cost of electrical energy based on the contracted coal output.

Tonnes of Coal Shipped per Year x 1,000,000	No. of Trips	Energy Cost Per Year	Demand Cost Per Year	Total Per Year	Cost Per Trip
8.5	953	$698,550	$708,000	$1,406,550	$1,476
13.5	1,514	1,109,800	708,000	1,817,800	1,201
17.0	1,906	1,397,100	708,000	2,105,100	1,104

Table 1 - Electrical Energy Cost

There have been a limited number of trips made using conventional diesel locomotives. Measurements show that 13,143 litres of diesel fuel are used on the return trip from the Quintette load-out to Tacheeda. Based on $0.367 per litre at the end of 1985, the round trip cost for diesel fuel is $4,823. Table 2 shows the projected annual fuel cost for conventional diesel operation at contracted quantities of coal.

Tonnes of Coal Shipped per Year x 1,000,000	No. of Trips	Estimated Annual Fuel Cost
8.5	953	$4,596,319
13.5	1,514	7,302,022
17.0	1,906	9,192,638

Table 2 - Projected Diesel Fuel Cost

A direct comparison can be made between the energy cost for electrical energy and diesel fuel.

Tonnes of Coal Shipped Per Year x 1,000,000	No. of Trips	Cost of Electrical Energy	Estimated Cost of Diesel Fuel	Cost Saving Per Year
8.5	953	$1,406,550	$4,596,319	$3,189,769
13.5	1,514	1,817,800	7,302,022	5,484,222
17.0	1,906	2,105,100	9,192,638	7,087,538

Table 3 - Comparison of Electrical Energy Cost to Diesel Fuel Cost

MAINTENANCE COSTS

Maintenance costs related to the electrification of the Tumbler Subdivision for the first year of operation are presented herein. Since it takes a few years of data collection to iron out the idiosyncracies in both the maintenance performed and the methods of reporting it, these costs are to be considered as a guideline only.

Locomotives

During 1985, there was a substantial amount of development work being done on the electric locomotives along with the scheduled maintenance work. At this time it is reasonable to expect that the cost of maintaining the electric locomotives will be as shown in Table 4.

Class of Inspection	Labour	Material	Annual Cost
Daily Trip Inspection	$45	$45	$32,850
45 Day Inspection	$570	$60	$5,000
Annual Inspection	$1,000	$60	$1,060
Air-brake Check (6-12-24 months)	$250	$730	$980
Repair and Service (annual estimated)			$45,400
Backshop - rewire and repaint every 10 years			$3,500/yr
			$88,790/yr

Table 4 - Estimated Maintenance Costs for Electric Locomotives

These costs remain constant unless the electric locomotives were to run in excess of 240,000 kilometers per year. At the maximum contracted tonnages, the electric locomotives are anticipated to run not more than 165,000 kms per year. Historically it has been BC Rail's experience that a typical 3000 hp road switcher's maintenance cost is in the order of $0.96 per kilometer. However, it must be noted that the electric locomotives used on the Tumbler Subdivision do the work of 1-1/2 conventional locomotives. Therefore, the maintenance cost for equivalent diesel-electric power should be taken as $1.44 per kilometer. Table 5 compares the estimated annual maintenance costs of the electric locomotives to the expected annual maintenance costs of diesel locomotives at the contracted annual tonnages of coal to be hauled.

Tonnes of Coal Shipped per Year x 1,000,000	Electric Locomotive Maintenance	Diesel Locomotive Maintenance
8.5	$621,530 (7 locos)	$1,180,800 (10 locos)
13.5	887,900 (10 locos)	1,872,000 (15 locos)
17.0	887,900 (10 locos)	2,361,600 (15 locos)

Table 5 - Comparison of Annual Maintenance Costs of Electric vs Diesel Locomotives

Catenary and Power Supply

The catenary system was completed in mid 1984. 1985 was the first full year that the electrification system was operational in its entirety. The maintenance has been performed by two maintenance crews, one supervisor and one catenary engineer. The crews each use one speeder and one high-rail equipped bucket truck. One maintenance crew is based at each end of the catenary system. The easterly crew of three looks after 67 kms of catenary including the Table Tunnel and the capacitor/harmonic filter station, and the westerly crew of four looks after 63 kms of catenary including the Wolverine Tunnel, 15 kms of catenary in the load-out loops and the substation with its related feeder line. Additional men were hired on an as-needed basis for emergency work.

During 1985, these crews worked 15,305 man-hours on maintenance. This is broken down into catenary maintenance, ice removal, mishaps and general operations as shown in Table 6.

Catenary & power supply maintenance	8,543 man-hours
Ice removal	3,082
Mishaps	2,514
Operations	1,166
Sub-Total	15,305 man-hours
Supervision	3,152 man-hours

Table 6 - Labour Distribution for Catenary Maintenance Crews

The labour analysis further shows that the 8,543 hours used in the catenary and power supply maintenance was made up of 5,300 hours of catenary maintenance in the open country, 1,205 hours of tunnel catenary maintenance, 605 hours of power supply maintenance, and 1,433 hours spent on unscheduled maintenance, vehicle servicing, training and work planning.

The maintenance of the catenary in the open country average 33.3 man-hours per kilometer as there is a total of 159 km of catenary including the mainline, sidings and loops. Similarly, the catenary maintenance in the tunnels averages 80.3 man-hours per kilometer. The additional time spent on catenary maintenance in the tunnels was primarily due to the need to clean the insulators on a regular basis

due to contamination caused by the operation of diesel-electric locomotives in the tunnels.

Insulator cleaning will decrease appreciably now that diesel locomotives are no longer used. Insulator cleaning on the open country catenary insulators is not carried out at such frequent intervals.

The cost of ice removal in the tunnels will decrease as the extent of tunnel insulation is increased.

The equipment to be used by the maintenance crews is charged at $500 per month for a bucket-truck and $350 per month for a speeder.

There are two bucket-trucks and two speeders used all year. The total vehicle cost is therefore $20,400.

The cost of labour for non-supervisory personnel working on electrification maintenance in 1985 averaged $26.50 per hour. This includes pay, fringe benefits and board loss. Supervisory time was charged at $28.35 per hour. A summary of labour costs is shown in Table 7.

Catenary & power supply maintenance	$226,400
Ice removal	81,650
Mishaps	66,600
Operations	30,900
Supervision	89,360
Vehicles	20,400
Total	$515,310

Table 7 - Labour Cost Distribution for Catenary Maintenance Crews (1985)

It is projected that the annual maintenance cost for the catenary and power supply will be reduced by a reduction in supervision, ice removal, mishaps and operations costs. Table 8 shows the projected annual cost for the catenary maintenance crews for 1986 and on.

Catenary & power supply maintenance	$226,000
Ice removal	40,000
Supervision	59,300
Vehicles	20,400
Total	$345,700

Table 8 - Projected Labour Cost for Catenary Maintenance Crews (1985 $)

SUMMARY

The operating and maintenance costs for 1984 and 1985 are shown in Appendix A. During 1984, a large number of trips were made with diesel power. The maintenance for the diesel locomotives must be added to the cost of maintaining the seven electric locomotives. The higher fuel cost for the electric locomotives is due to the demand costs being spread over fewer trips. The average cost of net fuel per trip in 1984 was $5,513. This is due to the large number of diesel locomotives used. During 1985, the electric locomotives had a higher utilization as the down time was reduced. By using more electric locomotives, but still needing some diesel power, the electric demand cost is spread over more trips and the net fuel cost per trip was reduced to $4,427 per trip.

During 1986, all coal will be moved with electric locomotives on the Tumbler Subdivision. It is expected that 8.5 million tonnes of coal will be hauled in 1986 and on. By eliminating the diesel locomotives, only electrical energy is used resulting in a reduction in the net energy cost per trip to $1,476.

The projected rate of return on the additional capital required to electrify the Tumbler Subdivision is 62.85% when the funding provided by various government agencies is considered. When considered without the funding, the rate of return on the additional capital is 20.25%. These rates of return are based on achieving 8.5 million tonnes of coal transportation per year.

Table 9 summarizes the increased savings when 8.5, 13.5 and 17.0 million tonnes of coal are transported per year.

The electrification of the Tumbler Subdivision has proven to be both feasible and economical. This project has successfully demonstrated the economies of 50 kilovolt electrification for railroads. The technology has been developed and can be implemented on the national systems wherever heavy tonnages, long grades, high speeds or long tunnels are encountered.

	8.5 Million Tonnes per Year (953 trips per year)		13.5 Million Tonnes per Year (1,514 trips per year)		17.0 Million Tonnes per Year (1,906 trips per year)	
	Electric	Diesel	Electric	Diesel	Electric	Diesel
Capital Cost						
Locomotives (1)	18,366	17,000	26,160	25,500	26,160	25,500
Power supply & catenary (2)	31,420	-	31,420	-	31,420	-
Tunnel ventilation (2)	-	21,700	-	21,700	-	21,700
	49,786	38,700	57,580	47,200	57,580	47,200
Maintenance Cost						
Locomotives	622	1,181	888	1,872	888	2,362
Power supply & catenary	345	-	345	-	345	-
Tunnel ventilation	-	230	-	230	-	230
	967	1,411	1,233	2,102	1,233	2,592
Operating Cost						
Energy	1,407	4,596	1,818	7,302	2,105	9,193
Total Maintenance & Operating	2,374	6,007	3,051	9,404	3,338	11,785
Net annual savings	3,633		6,353		8,447	

Table 9 - Summary of Cost Difference Between Electric and Diesel Operation for 1986 and On (x $1,000)

(1) The cost of locomotives is the 1983 purchase cost.
All other costs are in 1985 dollars.

(2) Includes interest during construction.

APPENDIX A

FINANCIAL SUMMARY

BRITISH COLUMBIA RAILWAY COMPANY
TUMBLER RIDGE BRANCH LINE ELECTRIFICATION

8.5 MILLION TONNES

	ELECTRIC	DIESEL	SAVINGS (COSTS)
CAPITAL COST			
LOCOMOTIVES	18,366,000	17,000,000	(1,366,000)
POWER SUPPLY & CATENARY (5)	31,420,000		(31,420,000)
TUNNEL VENTILATION (5)		21,700,000	21,700,000
	49,786,000	38,700,000	(11,086,000)
LESS: FUNDING	(9,563,000)		9,563,000
	40,223,000	38,700,000	(1,523,000)
1984 (5.3 mill tonnes - 588 trips)			
FUEL (1)	3,242,000	2,730,000	(512,000)
MAINTENANCE			
LOCOMOTIVES (3)	1,050,000	700,000	(350,000)
POWER SUPPLY & CATENARY (4)	495,000		(495,000)
TUNNEL VENTILATION (4)		220,000	220,000
	4,787,000	3,650,000	(1,137,000)
1985 (7.6 mill tonnes - 851 trips)			
FUEL (2)	3,768,000	4,100,000	332,000
MAINTENANCE			
LOCOMOTIVES (3)	986,000	1,050,000	64,000
POWER SUPPLY & CATENARY	515,000		(515,000)
TUNNEL VENTILATION		230,000	230,000
	5,269,000	5,380,000	111,000
1986 & ON			
FUEL	1,407,000	4,596,000	3,189,000
MAINTENANCE			
LOCOMOTIVES	622,000	1,181,000	559,000
POWER SUPPLY & CATENARY	345,000		(345,000)
TUNNEL VENTILATION		230,000	230,000
	2,374,000	6,007,000	3,633,000

(1) 1984 FUEL COSTS:
ELECTRIC: actual fuel cost 1984 $ of $3,242,000
DIESEL: prorata based on # of trips-1984 $

(2) 1985 FUEL COSTS:
ELECTRIC: actual fuel cost 1985 $ of $3,768,000
DIESEL: prorata based on # of trips-1985 $

(3) 1984 & 1985 LOCOMOTIVE MAINTENANCE:
ELECTRIC: 1985 costs for electric's plus maintenance on the proportionate number of trips with diesel locomotives ('84 costs in 1984 $)
DIESEL : 1985 costs based on the actual number of diesel trips ('84 costs in 1984 $)

(4) 1984 costs in 1984 $

(5) includes interest during construction

Treasury, 21-Mar-86

BRITISH COLUMBIA RAILWAY COMPANY

TUMBLER RIDGE BRANCH LINE ELECTRIFICATION
WITHOUT FUNDING

Annual cost/savings (in constant dollars)
in the 20 year period 1984 - 2003

YEAR	ADDITIONAL CAPITAL COST	FUEL	LOCOMOTIVE MAINTENANCE	VENTILATION MAINTENANCE	CATENARY MAINTENANCE	TOTAL
1983	(11,086,000)					(11,086,000)
1984		(512,000)	(350,000)	220,000	(495,000)	(1,137,000)
1985		332,000	64,000	230,000	(515,000)	111,000
1986		3,189,000	559,000	230,000	(345,000)	3,633,000
1987		3,189,000	559,000	230,000	(345,000)	3,633,000
1988		3,189,000	559,000	230,000	(345,000)	3,633,000
1989		3,189,000	559,000	230,000	(345,000)	3,633,000
1990		3,189,000	559,000	230,000	(345,000)	3,633,000
1991		3,189,000	559,000	230,000	(345,000)	3,633,000
1992		3,189,000	559,000	230,000	(345,000)	3,633,000
1993		3,189,000	559,000	230,000	(345,000)	3,633,000
1994		3,189,000	559,000	230,000	(345,000)	3,633,000
1995		3,189,000	559,000	230,000	(345,000)	3,633,000
1996		3,189,000	559,000	230,000	(345,000)	3,633,000
1997		3,189,000	559,000	230,000	(345,000)	3,633,000
1998		3,189,000	559,000	230,000	(345,000)	3,633,000
1999		3,189,000	559,000	230,000	(345,000)	3,633,000
2000		3,189,000	559,000	230,000	(345,000)	3,633,000
2001		3,189,000	559,000	230,000	(345,000)	3,633,000
2002		3,189,000	559,000	230,000	(345,000)	3,633,000
2003		3,189,000	559,000	230,000	(345,000)	3,633,000
	(11,086,000)	57,222,000	9,776,000	4,590,000	(7,220,000)	53,282,000

RATE OF RETURN 20.2548%

Treasury, 21-Mar-86

BRITISH COLUMBIA RAILWAY COMPANY

TUMBLER RIDGE BRANCH LINE ELECTRIFICATION
WITH FUNDING

Annual cost/savings (in constant dollars)
in the 20 year period 1984 - 2003

YEAR	ADDITIONAL CAPITAL COST	FUEL	LOCOMOTIVE MAINTENANCE	VENTILATION MAINTENANCE	CATENARY MAINTENANCE	TOTAL
1983	(1,523,000)					(1,523,000)
1984		(512,000)	(350,000)	220,000	(495,000)	(1,137,000)
1985		332,000	64,000	230,000	(515,000)	111,000
1986		3,189,000	559,000	230,000	(345,000)	3,633,000
1987		3,189,000	559,000	230,000	(345,000)	3,633,000
1988		3,189,000	559,000	230,000	(345,000)	3,633,000
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2000		3,189,000	559,000	230,000	(345,000)	3,633,000
2001		3,189,000	559,000	230,000	(345,000)	3,633,000
2002		3,189,000	559,000	230,000	(345,000)	3,633,000
2003		3,189,000	559,000	230,000	(345,000)	3,633,000
	(1,523,000)	57,222,000	9,776,000	4,590,000	(7,220,000)	62,845,000

RATE OF RETURN 62.8495%

Treasury, 21-Mar-86

POOR
QUALITY
ORIGINAL